

**EFFECT OF DESERT LOCUST OUTBREAKS ON AGRICULTURAL PRODUCTION
OF SMALLHOLDER FARMERS IN KARAMOJA REGION, UGANDA**

BY

LUTAAYA NOAH

Reg No. 19/U/GMAG/18998/PD

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DECLARATION

I Lutaaya Noah declare that this research work has never been submitted or presented to any university or institution of higher learning for any award. Where ideas of other scholars have been used, they have been acknowledged by way of citation and full list referencing.

Signed.....

Date.....

Lutaaya Noah

19/U/GMAG/18998/PD

APPROVAL

I certify that this dissertation has been compiled under our guidance and supervision. It is ready for submission with my approval.

Signed.....

Date.....

ASSOC. PROFESSOR BARASA BERNARD

Signed.....

Date.....

DR. GABIRI GEOFREY

DEDICATION

I dedicate this dissertation to my children; Lutaaya Abdul Haleem, Nakiganda Husnah and Habeebah N as well as my parents; Ssemwanga Abuka Mohammad and Mmeme Mariam.

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ACRONYMS

ESA	-	European Space Agency
FAO	-	Food and Agriculture Organisation of the United Nations
FGD	-	Focus Group Discussion
NDVI	-	Normalized Distance Vegetation Index
NGO	-	Non-Governmental Organisations
SAVI	-	Soil Adjusted Vegetation Index
UN	-	United Nations
UNC	-	United Nations Convention
UNDP	-	United Nations Development Programme
WFP	-	World Food Programme

ABSTRACT

The 2020 desert locust invasions invoked fears in Eastern Africa, including Uganda, but more so in the Karamoja region, due to their potential to devour crop fields and pasturelands, which are major livelihood sources for agro-pastoralists. This research assessed the duration and timing of the invasions by desert locusts, the impact they had on agricultural output, and the efficacy of the control strategies put in place in the districts of Amudat, Abim, Moroto, and Nakapiripirit. Specifically, it was intended to analyze the time of invasion and length of stay of the locusts in that area, determinant factors for the invasions, effects on cropland and pastureland for livestock, and to evaluate the effectiveness of the measures that were applied. To gather more than one data from households and local leaders in the same study, a cross-sectional study approach was employed. This was guided by the need to capture a snapshot of the locust invasions' impact over a single period, which allowed for the efficient collection and comparison of diverse responses from affected communities. With the assistance of well-trained research assistants well versed with the karamojong local languages, a questionnaire for a household survey was administered to 183 respondents who included elders, youths, opinion leaders, and local council 1 chairpersons chosen by sampling technique. The views on the subject matter from the local leaders and small holder farmers in Amudat and Moroto were gathered through two corresponding focused group discussions. Numeric data was analyzed using multiple response, chi-square, and paired t-test techniques, whereas qualitative data underwent content analysis techniques. The findings reveal that the most favorable factors that attracted the pests were vegetation type, strong dry winds, and soil type (sandy) ($P < 0.05$). The effects of the invasions reported include destruction of trees (43%) and grass cover (39%), increased replanting costs (28%), interference with plant flowering (26%), and shifts in season planting (24% in the locales of the invasions). Desert locusts significantly ($P < 0.05$) affected livestock and crop production by reducing grass and tree vegetation that cattle feed on and destroying sprouting crops. These culminated in a significant ($P < 0.05$) reduction in household income, an increase in the need for food purchases, and the use of less land (74%) for agriculture. In response to the invasions, ground spraying (68%) and aerial spraying (29%) were the most effective measures for desert locust control. To enhance resilience among agro-pastoralists against future invasions, the study recommends support for acquiring specialized spraying equipment to enable more effective and timely control efforts.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Locusts have been invading planet Earth since the start of human civilization, associated with the domestication of crops, plants and animals. Gómez et al. (2019) argue that migrating locust swarms were first recognized as a threat to agricultural communities in the Middle East as early as 10,000 years ago. According to the Food and Agriculture Organization (FAO) of the United Nations (2020), locusts are among the most ancient migratory pests that have devastated crops worldwide for generations.

There are up to 12,000 different species of locusts in the grasshopper family, but the most destructive is the Desert Locust (*Schistocerca gregaria*) (Peng et al., 2020). Other species include the Red Locust (*N. septemfasciata*) in Tanzania, the Australian Plague (*Chortoicetes terminifera*), the Spur Throated (*Austracris guttulosa*), the Migratory Locust (*Locusta migratoria*), the Rocky Mountain Locust (*Melanoplus spretus* Walsh), the Bombay Locust (*Nomadacris succincta* L), the Tree Locust (*Anacridium rubrispinum* B.B.), the South American Locust (*Schistocerca cancellata*), among others (Le Gall et al., 2019a). Under optimal conditions, these rapidly increase in numbers and swarms migrate long distances consuming most of the green cover in their pathway, posing threats to human food security (FAO, 2020a). It is from such a character that desert locusts have been known for millennia as fear-instilling pests, capable of forming large swarms covering several hundred square kilometers, attacking cultivated areas, and inflicting damage on a spectacular scale (Kassegn & Endris, 2021).

Desert locusts have historically invaded arid and semi-arid regions, although they often spread out into non-arid lands located hundreds to thousands of kilometers away (Chen et al., 2020). The

worst wrath of these pests has been witnessed and recorded in India, Arabian Peninsula, Yemen, Saudi Arabia, Pakistan, and Central Asia like in Kazakhstan, North Eastern, and South Western Asia (Chen et al., 2020; Le Gall et al., 2019a). In the last half of the century, major locust outbreaks have also been recorded in most of the warmer parts of Australia, North America like the Rocky Mountain Locust (*Melanoplus spretus* Walsh), and South America in Argentina (Veran et al., 2015; Zhang et al., 2019). The dry regions of Africa have witnessed an equal share of the world desert locust outbreaks. The Arabian Peninsula was struck by desert locusts in 2020 which was fueled by several cyclones characterized by wet weather in the previous 18 months which favoured vegetation growth onto which locusts feed (Le Gall et al., 2019b). Under these conditions, the population of locusts expanded considerably before they spread into Ethiopia and Somalia across the Red Sea and Gulf of Aden (Sharmila, 2020).

In East Africa, the spillover of locusts from Arabia saw these pests enter Kenya through the Northern part of the country and finally into Uganda, a trend that dates back to 1931 (Peng et al., 2020). The first wave of desert locust swarms invaded Uganda in February 2020 from neighboring Kenya, while the second wave arrived on April 3, 2020, via Amudat, passing through the sub-counties of Karita and Loroo, before expanding to other districts in the Karamoja sub-region. 89 sites in 21 districts were reported to have locust sightings in February of the 2020 invasions; 16 sites reported sightings in March, 34 locations in April, and just 8 places in May. Between 7th and 11th July, another 2 locust swarms were sighted and reported by surveillance teams in Rupa and Naiput Sub-Counties in Moroto District (FAO, 2020). This means that the 2020 locust invasions occupied Karamoja sub region for the bigger part of the planting season according to the local agronomic calendar.

Desert locust invasions cause extensive damage to vegetation and crops, resulting in losses amounting to millions of dollars in affected areas. When they swarm, the dense, settled locusts can break branches of trees and bushes under their collective weight, damaging crops like coffee in East Africa—even though they seldom eat the foliage directly (Peng et al., 2020). The Karamoja region, where many smallholder farmers have limited access to resources, was particularly vulnerable to the invasion, as they lack the resilience to withstand such climate change-related hazards (FAO, 2020; Kassie, 2013; Mulinde, 2019). This invasion affected smallholder farmers' livelihoods and worsened food security in the area (FAO, 2020b; Kassegn & Endris, 2021).

While locust invasions are generally driven by climate-related factors, vegetation cover, and soil or sand conditions, and are known to impact agricultural productivity and the livelihoods of farmers (Le Gall et al., 2019a; Maeno et al., 2019; Meynard et al., 2020; Saini et al., 2021), the recent occurrences in northeastern Uganda were on an unprecedented scale. According to FAO (2020), in terms of swarm size and destruction, this locust upsurge in East Africa is the most severe in 25 years, and in Kenya, it was the worst in 70 years. Additionally, information on the specific conditions that enabled these recurring invasions, and the subsequent impacts on livestock, agricultural productivity, and food security among smallholder agro-pastoralists, was limited. In northeastern Uganda's semi-arid climate, where harsh weather often leads to low agricultural output, the crop and grazing fields that harbor these pests face further threats from climate change-related events like locust invasions. Given this context, field research was critical to assess the impact on smallholder farmers in Uganda's semi-arid northeast (Egeru et al., 2014)

The situation in northeastern Uganda is notably different due to the extreme scale of the 2020 locust invasion, which exceeded previous occurrences in both swarm size and the extent of damage. The lack of prior knowledge about conditions that favored the outbreak left the region

less prepared to respond effectively, especially as smallholder agro-pastoralists already faced challenges with limited resources and resilience-building measures. Additionally, northeastern Uganda's semi-arid climate and typically low agricultural productivity exacerbate the locusts' impact, as pests further damage the few available resources vital to local food security and livelihoods. This unique combination of environmental vulnerability, severe locust impact, and inadequate resilience measures made the situation in northeastern Uganda particularly devastating.

1.2 Statement of the Problem

Desert locusts led to significant destruction of foliage of all kinds including crops, pasture, and fodder in the Karamoja sub region; negatively affecting livelihoods and causing food security concerns (FAO, 2020). Whereas in June and July 2020, the Regional Food Security and Nutrition Working Group (RFSNWG) conducted an impact study in Desert Locust-affected countries, to evaluate how much the desert locust invasions had harmed farmers and the impacted households (FAO, 2020), the assessment was for the first invasions yet other episodes ensued later in the second rainfall season. According to FAO (2020), the invasions of desert locusts continue to pose a danger to the food security and agricultural livelihoods of over 800 households (mostly smallholder farmers) in northeastern Uganda; though the extent and nature of this impact remain unclear.

Food security is multidimensional and multi-faceted thus extensive analysis is called for under hazard-stricken conditions (Ingutia & Sumelius, 2022). Unless meticulous efforts are made to evaluate the impact created by past events and the effective measures to protect livelihoods and improve food security, future invasions are likely to ravage the already resource-constrained region. Previous related studies in the area (FAO, 2020b; 2021; Yamano et al., 2021), have also paid little attention to the assessment of the ability of the smallholder farmers to control and

manage future locust invasions, based on the effectiveness of the previously applied measures. This study filled this gap by assessing the 2020 desert locust invasion factors, the extent of the damages to pastureland, crop fields, and food security, and the efficacy of the control measures implemented in the Karamoja sub-region in Northeastern Uganda, using field-based evidence.

1.3 Study Objectives and Research Questions

1.3.1 General Objective

The study was intended to examine the effects of desert locust outbreaks on agricultural production among small holder farmers in the Karamoja sub region of Uganda.

1.3.2 Specific Objectives

Specifically, this study sought to attain the following objectives

- i. To establish the timing, duration and determinant factors of the 2020 desert locust invasions in Karamoja sub region in Uganda.
- ii. To assess the effects of desert locust invasion on crop and livestock production in Karamoja sub-region.
- iii. To determine the effects of desert locust invasion on household food security (availability, purchases and consumption) by smallholder farmers in Karamoja sub region
- iv. To evaluate the effectiveness of the implemented desert locust management measures in Karamoja sub region.

1.3.3 Research Questions

- i. What is the timing, duration and determinant factors of desert locust invasions in Karamoja sub-region?
- ii. How do desert locusts affect crop and pasture production?
- iii. What is the effect of desert locust outbreaks on small holder farmers' household food availability, purchase and consumption?
- iv. What are the most effective desert locust control measures used in Karamoja sub region?

1.4 Significance of the Study

The findings of this study ought to contribute additional information on desert locust outbreak dynamics in North Eastern Uganda. Government ministries that deal with chemicals, equipment, funding, and capacity building—such as the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), the Ministry of Disaster Preparedness, and sister organs—need this information in order to better position themselves and provide timely interventions against the desert locusts.

The results may be useful in assessing how desert locusts affect food security, which is important information for determining the population that requires food assistance and/or agricultural investment support from UN agencies such as the World Food Programme (WFP), FAO, and government and non-governmental organizations.

The study adds to the body of literature already available on the vulnerabilities of plants and livelihoods caused by desert locust invasion, which will be a valuable resource for future

researchers. To determine the impact of the later variable on the rise in the size of future locust invasions, the results can also be compared to scenarios of climate change.

1.5 Scope of the Study

The study was carried out in the districts of Abim, Amudat, Nakapiripirit, and Moroto in northeastern Uganda. These were selected for the study because they formed the major pathway for the 2020 desert locusts' invasions in Uganda from Kenya as reported in the media. During Uganda's 2020 desert locust invasion, reports of sightings of the first and second invasions were also made in these districts. The study's main objectives were to evaluate the 2020 desert locust invasions and the factors that led to them, the effects on livestock production, as well as the emerging effects on agropastoralist livelihoods and the efficacy of the control measures put in place in the four districts of the Karamoja region. Socio-economic data was collected for three months between June and August 2021 and the analysis of desert locust dynamics and effects were for a period of two years (i.e., 2019 and 2020).

1.6 Conceptual framework

The relationship between desert locust invasions, their determining factors, and their effects on vegetation cover and agricultural production particularly on crop and livestock farming among agropastoral communities is illustrated in the conceptual framework as shown in Figure 1.1. In this framework, desert locust invasions are conceptualized as the Independent variable, while the Dependent variables include changes in vegetation cover, agricultural production (both crop and livestock), and impacts on livelihoods and food security. Desert locusts typically invade both crop fields and pasturelands, consuming vegetation vital for livestock grazing and crop growth. This invasion leads to a reduction in vegetation cover, directly impacting agricultural production. As locusts devour crops and grazing vegetation, crop yields drop and livestock production suffers due

to a lack of pasture. This has cascading effects on agropastoral communities, where both crop and livestock farming are crucial for livelihoods and food security.

The effects of locust invasions extend to two primary areas: livelihoods and food security. Livelihoods are affected as key agricultural activities before and after invasions differ significantly, with reduced income opportunities from both crop sales and livestock products. In terms of food security, locust invasions compromise food availability for current consumption, reduce quantities stored for future use, and increase the quantity of food that must be purchased, thus straining household resources. Several factors influence the likelihood and intensity of desert locust invasions. These determinant factors include climatic factors (such as rainfall, temperature, and wind patterns), vegetation conditions (particularly fresh sprouting that attracts locusts), and bio-edaphic factors (like soil moisture and sand composition). Insights from local communities can help identify which of these factors were most significant during specific invasion events in Karamoja.

In response to the destructive effects of locust invasions on vegetation and agricultural production, various intervention measures are implemented at different levels. The effectiveness of these interventions varies, influenced by factors such as timing, scale, and resources available for locust control efforts. Understanding the interplay of climatic, environmental, and socio-economic factors within this framework provides a clearer view of the challenges faced by agropastoral communities and the need for targeted, effective interventions to protect livelihoods and food security against locust invasions.

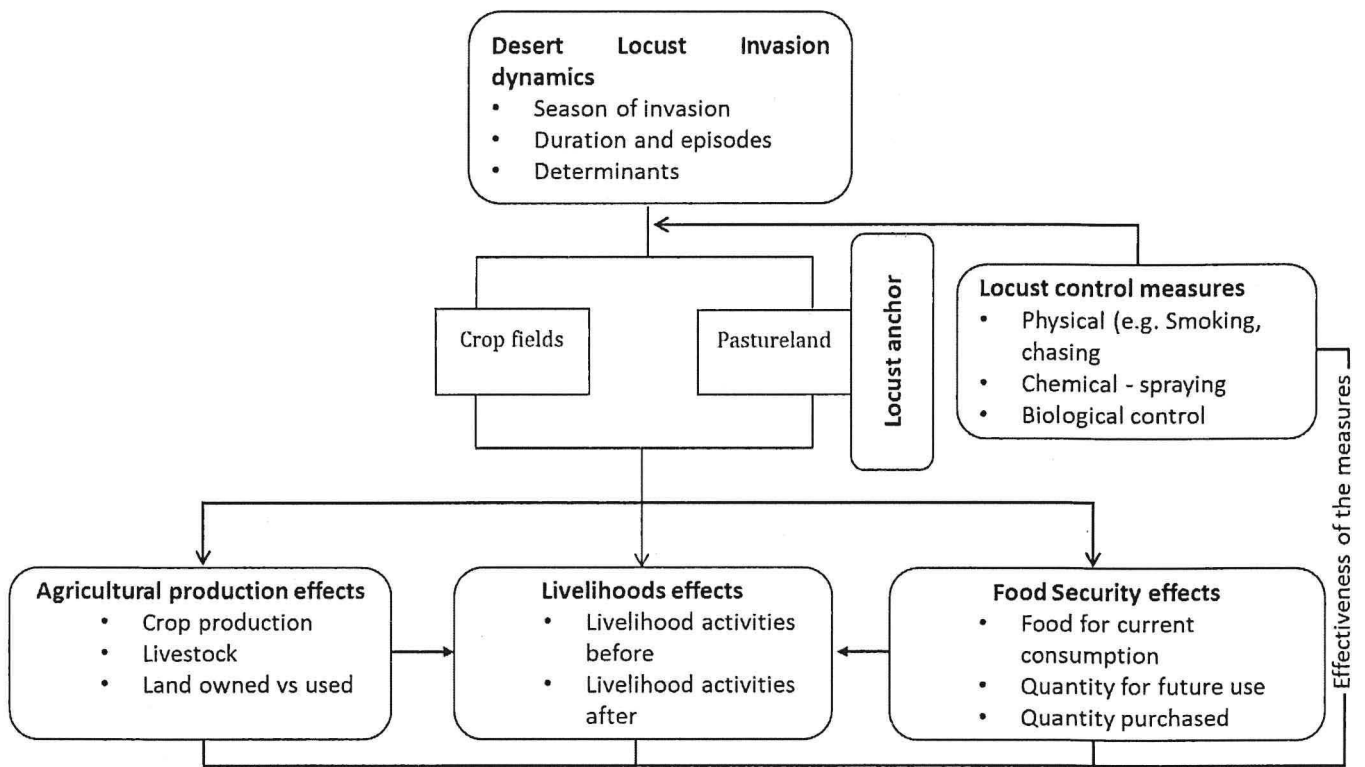


Figure 1.1: The Conceptual framework (Source, Author)

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This section presents an overview of the body of research on desert locust invasions and vegetation cover and livelihood impacts. The documents reviewed include policy papers, journal articles, textbooks, bullets and others sourced electronically from online libraries.

2.1 Desert Locust Invasion Dynamics

2.1.1 Timing, Duration, and Episodes

A locust is a special type of grasshopper (Orthoptera Acrididae) (Stephen, Simpson, and Sword, 2006). According to Joshi et al. (2020), locusts are a group of various species of short-horned grasshoppers in the Acrididae family that exhibit swarming behavior. There are three stages in a locust's life cycle: the adult, nymph, and egg. The nymphs resemble adults in appearance and behavior. However, they are unable to reproduce (Markle, 2008). In the top 15 centimeters of damp soil, the female locust deposits her eggs. It takes roughly two weeks for the eggs to hatch, though this period can range from ten to sixty-five days depending on environmental conditions (Ashall and Ellis, 1962; Roffey and Popov, 1968). Depending on the temperature, the developing hoppers go through five to six stages over a period of thirty to forty days. At the last molt, the young adult, also known as the fledgling, emerges (Cressman, 1996). Locusts undergo incomplete metamorphosis, allowing them to change both their appearance and behavior, such as transitioning from a solitary to a gregarious form. The solitary form is typically brown or green, which allows locusts to camouflage with their food plants. The gregarious form, however, is more conspicuous due to its bright coloration, which enables gregarious locusts to see and stay together (Markle,

2008). Over successive generations of crowding, the tendency to exhibit gregarious behavior develops and is passed down from parents to offspring (Islam et al., 1994).

Swarms of adult desert locusts can travel vast distances rapidly. Desert locust migration is influenced by temperature and wind, and swarms are typically restricted to semi-arid and arid deserts in Southwest Asia, Africa, and the Middle East, regions receiving less than 200 mm of rainfall per year. This habitat covers 30 countries and spans approximately 16 million km² (Cressman, 1996).

2.1.2 Desert Locust Invasion Determinant Factors

Desert locusts inhabit and feed on various forms of vegetation, and when a swarm invades an area, it remains until the plant matter is fully consumed. This results in a "footprint" that can help trace their spatial distribution and migration routes. Recent advancements in remote sensing technology have improved the ability to monitor locust activity due to the limitations of field data, such as restricted spatial and temporal scales, data inconsistencies, and reliability issues (Gobron et al., 2000). According to Wang et al. (2021), since 2019, large-scale swarms of desert locusts have posed a threat to native flora and agricultural crops in East Africa and West Asia, culminating in a severe locust upsurge in early 2020. Environmental factors such as rainfall, temperature, winds, soil moisture, and vegetation greenness influence desert locust breeding, maturation, gregarization, and migration (Cisse et al., 2013; Peng et al., 2020; Wang et al., 2021). Typically, climate serves as the primary determinant of these environmental factors that impact desert locust breeding. When rainfall occurs, soil and plants become moist, which is favorable for locust reproduction. Winds during the season further facilitate the movement of adult swarms.

Rainfall and vegetation features have created specific conditions for locust outbreaks in other regions as well (Veran et al., 2015). However, predictions about future outbreaks rely on the

presence of suitable initial hotspots and inverse environmental conditions. For instance, heavy rainfall events on the Arabian Peninsula in 2018 led to abundant vegetation and ideal soil moisture, attracting desert locusts. In the following year, as favorable conditions shifted to West Asia and Northeast Africa, the locust swarms also moved to these regions (Wang et al., 2021). In terms of geographical distribution, temperature and the leaf area index are significant factors for desert locust populations across Africa, Asia, and Europe (Chen et al., 2020). According to Wang et al. (2021), ample rainfall and fresh vegetation influenced locust breeding, reproduction, and gregarization in invasion-prone regions such as the Arabian Peninsula, West Asia, and Northeast Africa. Their study utilized long-term earth observation data to analyze the elements contributing to the early 2020 desert locust crisis and the resulting loss of vegetation.

Research conducted by Kimathi et al. (2020) using machine-learning algorithms identified areas of high risk for desert locust breeding, including large parts of Kenya and Sudan, northeastern Uganda, and southeastern and northern regions of South Sudan. While variations in invasion frequency exist, specific environmental variables unique to each area play a role, and these were identified as potential focal points for future study. This research also supported predictions from prior studies (e.g., Kimathi et al., 2020). Locust prediction studies require vast, accurate, and up-to-date spatial data (Piou et al., 2019). However, in countries where such data is limited (such as Uganda), researchers often have to rely on field measurements

Vegetation also influences the gregarization of desert locusts. Cisse et al. (2013) studied the effects of locust density, vegetation cover, and vegetation condition on the likelihood of detecting gregarious locusts, based on a 0.5 probability threshold for observing gregarization at specific density levels. Their findings indicated that low cover and dry vegetation led to a lower gregarization threshold, likely due to increased chances of individual locust contact. Dense, lush

vegetation, however, supported a higher gregarization threshold due to reduced individual contact as locusts dispersed more widely. The study defined "gregarization" as a locust adaptation strategy to diverse environmental conditions. Nonetheless, vegetation density is influenced by other environmental factors, such as climate and soil conditions, which should be factored into locust invasion analyses. Piou et al. (2019) further demonstrated the impact of soil moisture on locust gregarization, arguing that soil moisture dynamics play a significant role in desert locust population levels. Their study noted a specific pattern where soil moisture increased by more than $0.09 \text{ cm}^3/\text{cm}^3$ over a 20-day period, then decreased, creating conditions that could encourage locust sightings around 70 days later.

Although previous studies have examined the migratory routes and spatial distribution of desert locust outbreaks, the majority have focused on Asia and Australia (Jhiknaria, 2021; Peng et al., 2020), which experience different environmental conditions compared to Uganda. Additionally, subsequent invasion events may not always follow similar patterns, underscoring the need for localized assessments

2.2 Effect of desert locust invasion on crop and livestock production

Since desert locusts invade all forms of plant cover, including crop and grazing fields, they are considered one of the greatest threats to agricultural production (Skaf et al., 1990). The high potential for locust invasion episodes to adversely affect agricultural-based livelihoods exacerbates food security concerns (Peng et al., 2020). Kimathi et al. (2020) report that the livelihoods of people in the drier areas of East Africa are under significant threat, which worsens the state of food insecurity in these regions. According to the UNWP, at least 42% of households in Karamoja—a desert locust hotspot—are food insecure, although food insecurity levels vary significantly across households. Approximately 70% of households in the food-secure category hold cattle or poultry,

compared to less than 60% of households in the food-insecure category, according to Akabwai and Ateyo's 2007 research. Thus, desert locust invasions continue to affect the environment and economic development in regions already facing food security challenges. Food safety, on the other hand, influences the social stability of rural populations in climate-risk-prone, agriculture-dependent communities, such as the agro-pastoralists in the Karamoja sub-region of Uganda (Lecoq, 2003).

Kassegn and Endris (2021) report that the upsurge of desert locusts, coupled with the COVID-19 pandemic and severe flood events in East Africa, has compounded socio-economic conditions with devastating effects. Endris (2021) notes that locust invasions in East Africa exacerbated already existing food insecurity and compromised years of progress in development and livelihoods. Endris relied on secondary data sources to analyze the combined socio-economic effects of three concurrent disasters, including desert locust events.

The FAO (2020) conducted an assessment of seven regions affected by the desert locust, covering 29 districts. They reported that 50% of pasture in Somalia and Eastern Oromia was damaged during the 2020 invasion months, while 356,286 metric tonnes of cereal belonging to approximately 806,400 farming households were lost. Desert locusts were estimated to have devastated 1,350,000 hectares of pasture and browse, as well as 197,163 hectares of farmland. This worsening situation affected household food security as the quality and diversity of household diets deteriorated, with food insecurity increasing from 37% in 2019 to 41% in 2020. Since households were relying on food purchases, cereal prices rose while livestock prices stagnated. Many households could not harvest food crops to store for the off-season, thus requiring emergency food aid. Although households in Karamoja largely depend on pastoralism, some wetter parts of the region grow crops. However, they still rely on purchased food from the market; thus, effects on livestock

production reduce their income, limiting their ability to afford market-sold food. This study uses field survey data from smallholder farmers in specific regions of the Karamoja sub-region to evaluate the effects of desert locust outbreaks on crop and livestock production.

2.3 Broader Effects of Desert Locust Invasions on Agricultural Production and Food

Security in Karamoja

Desert locust invasions present severe disruptions to agricultural production and food security in regions heavily reliant on agriculture, like Karamoja. The destruction of crop fields and pasturelands directly impacts both food availability and the stability of agricultural-based livelihoods (FAO, 2020). As locust swarms consume nearly all types of vegetation, they strip the land bare, leaving little to no food for livestock and significantly reducing the harvests that households depend on both for subsistence and income (UNICEF, 2020). This loss leads to cascading effects on food security as households lose not only immediate food sources but also essential income, which many use to purchase other necessary food items (ReliefWeb, 2021).

For Karamoja, a region where households are predominantly agro-pastoralist, locust invasions threaten the entire ecosystem on which food production depends (FAO, 2020). In times of locust invasion, food scarcity can lead to sharp increases in market prices, pushing basic food items out of reach for many vulnerable households (World Bank, 2020). Consequently, food security in Karamoja deteriorates further, affecting household dietary diversity, quality, and availability. The UN World Food Programme (WFP) highlights that in Karamoja, food insecurity already affects 42% of households, a number that can rise significantly during locust invasions, compounding food scarcity issues and placing additional pressure on relief services and government resources (WFP, 2020). This broader impact on agricultural production and food security illustrates the

urgent need for effective locust control measures and support systems for affected communities (UN, 2020).

2.4 Specific Impacts of Desert Locusts on Smallholder Farmers' Household Food Security and Livelihoods

For smallholder farmers, locust invasions can have devastating impacts on crop yields, livestock health, and overall livelihood sustainability. The immediate loss of crops and pastures significantly affects the food security of these households, who may not have the means to cope with sudden production losses. As a result, many families become increasingly reliant on food purchases, which can become prohibitively expensive during and after locust invasions due to supply shortages.

Moreover, the financial strain of purchasing food can exacerbate existing poverty levels, as smallholder farmers often operate on tight margins. When locusts destroy crops, farmers not only lose their primary source of food but also miss out on potential income from surplus crops. The economic repercussions can lead to long-term food insecurity, especially if farmers are unable to recover in subsequent planting seasons.

2.5 Effectiveness of Desert Locust Invasion Management Measures

Many strategies can be employed to disrupt the desert locust's ability to reproduce, mature, form gregarious groups, and migrate, to prevent further destruction. Spraying chemicals and insecticides using combined aerial and ground approaches is the most common control measure in areas where desert locust infestations have previously occurred. Other methods include smoking/lighting fires, making loud noises to chase locusts away, trampling, biological control, trench trapping, and digging up locust egg pods (Sharma, 2015). Spraying hoppers early in their development can prove more effective for chemical control (Prior & Streett, 1997; Cressman & Fresco, 2001; Showler et

al., 2021). However, Zhang et al. (2019) caution that overuse of pesticides can have unfavorable environmental consequences. If incursions are discovered too late, pesticide application may become the only effective option. According to Showler et al. (2021), chemical spraying can be helpful in preventing locusts from reaching swarm status and damaging plantations, but the costs and disruptions involved can outweigh the benefits.

The success of applied control measures may vary depending on the resources available to the invaded community, the timing of interventions, the magnitude of invasion episodes, the spatial extent, and the technical expertise available to handle the situation (L. Zhang et al., 2019). Biological control methods, for example, require extensive research to ensure that the biological solution does not lead to another ecological disaster. At the household level, communities often resort to affordable methods, such as making loud noises by banging jerry cans, burning locust-infested fields, and other low-technical approaches. While these may temporarily alleviate the problem, their sustainability is highly questionable (Sharma, 2015). The current study evaluated the effectiveness of these control measures in the context of an economically constrained region with environmental challenges.

Effective desert locust control not only means eradicating swarms from an area but also avoiding the negative impacts of the actions taken. It should be noted that some locust control measures are feasible only at the household or community scale, while others are effective on a landscape scale. The effectiveness of these measures may vary accordingly. In historically locust-prone areas, control measures are often informed by past experience regarding their effectiveness (Van Huis, 2007). This study examined the desert locust control measures implemented during the 2020 desert locust outbreak in the Karamoja sub-region. Additionally, the effectiveness of these measures in

terms of timing, application location, precautions taken to protect humans and animals, pollution prevention, and community training were evaluated.

2.6 Summary of the Gaps Identified in the Literature

The literature indicates that desert locust invasions, although infrequent, can occur multiple times within a single year, often with increasing intensity. These invasions are largely influenced by uncontrollable climatic and environmental factors, such as rainfall and vegetation growth, allowing locust populations to expand and migrate widely. The socio-economic impacts are significant, particularly for agricultural communities, leading to reduced productivity, damaged livelihoods, and heightened food insecurity. Affected communities tend to use reactive control measures, which vary in effectiveness due to resource limitations and timing challenges. While some traditional methods offer temporary relief, their long-term viability is uncertain. Despite extensive documentation on the socio-economic effects and general control strategies, there is a lack of focused research on the adaptive capacities of smallholder farmers in high-risk areas like Karamoja. Specifically, the literature fails to assess how past control measures can inform resilient, locally tailored strategies for future locust management. This highlights the need for research to evaluate smallholder farmers' adaptive responses in Karamoja, assess the effectiveness of previous measures, and identify community-specific strategies for sustainable locust management amid future climatic uncertainties.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This section outlines the geographic focus of the research, the methodology that will be employed, the demographics of the target population, the determination of the appropriate number of participants, the strategies for selecting the sample, the procedures for gathering data, and the techniques for examining the data.

3.2 Description of the study area

This covers physical aspects of the study area including location, climate, topography, drainage, vegetation and geology, and soils of the study area. Other geographical aspects covered include population and ethnicity and land use activities in the survey area.

3.2.1 Location

The study area covers eight sub counties, taking two from each of the four districts of Abim, Amudat, Moroto and Nakapiripitit under Karamoja region of Northeastern Uganda (Figure 3.1). The sub counties include Alerek and Magamaga (Abim), Rupa and Katikikekile (Moroto), Loroo and Amudat (Amudat) and Kakomongole and Moruita (Nakapiripirit). The study area is bordered by South Sudan in the north and Kenya in the East. It lies within longitudes 33° 31' 12" and 35° 1' 53" East and latitudes 1° 22' 5" and 3° 9' 34" North. The study area is selected because it was recently invaded by deadly desert locusts in 2020 and henceforth provides the best area to investigate their effects on vegetation and agricultural production (FAO, 2020). The sub counties selected were those in which locust sightings had been reported during the invasions.

3.2.2 Climate

The semi-arid Karamoja sub-region is distinguished by erratic rainfall patterns and elevated temperatures (Dyer et al., 2008; Mubiru, 2010). Rainfall ranges between 750 mm and 1000 mm per annum, which is unevenly distributed on a spatial and temporal scale and with the highest amounts experienced in the southern extent between March-May (NEMA, 2010). The climatic conditions here restrict land use to pastoralism and some small annual crop production and mining (NEMA, 2008).

3.2.3 Relief

Volcanic mountains including Kadam in Nakapiripirit, Napak in Napak district, Moroto in Moroto district, and residual hills covering much of the rolling plains to the west and northern parts of the region characterize the region's geomorphology. The topography of the area is tilted in an east-west direction with the eastern side hosting ancient mountain ranges, the west being dominated by plains dotted with residual hills, and rock outcrops.

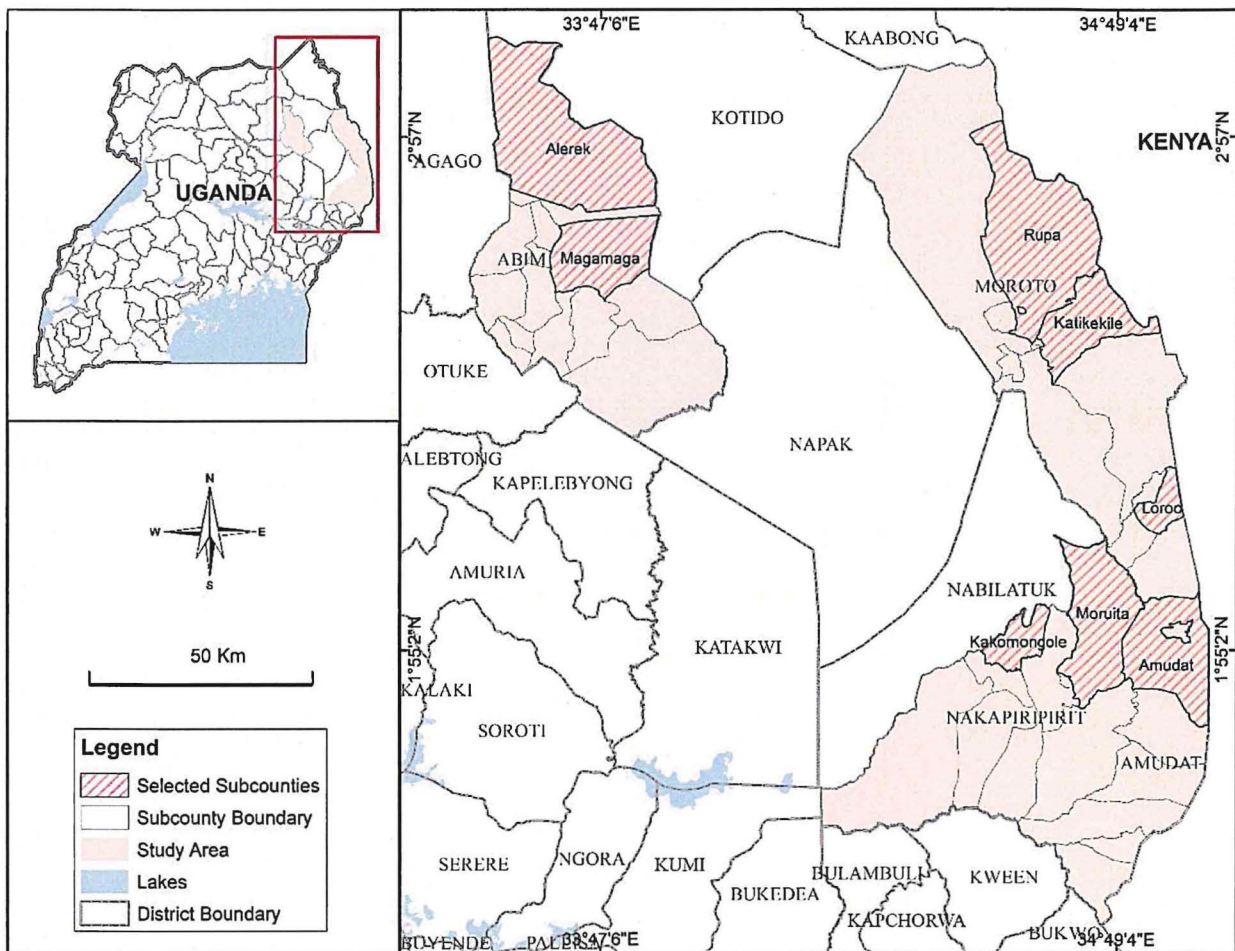


Figure 2: Location of the study area

3.2.4 Drainage

The hills and mountains to Karamoja's east are the source of several ephemeral streams and rivers that travel west and south. The region lies within two sub-catchments of Kyoga, and Aswa. Namalu is the main annual river flowing through the study area under the Kyoga catchment whilst others are perennial rivers. These rivers have deep incisions, are sand-filled, and may serve as a significant supply of water during the dry seasons (Egeru et al., 2015). Most of the rivers in the region are seasonal bursting the banks during the short rainfall season.

3.2.5 Vegetation

The vegetation cover in Karamoja is made up of wooded and grassland savanna mainly in the south but the vegetation translates into thickets and bush land in the northwestern direction. Given that the grasslands are broken up by solitary forests on the sides and summits of mountains, both woody and herbaceous species are common there (Egeru et al., 2015). The woody vegetation is classified as tropical deciduous vegetation while a small proportion (Namalu-Nakapiripiriti district) of the land area is occupied vegetation.

3.2.6 Geology and soils

Soils with sands, low-water-holding loamy sands, and black, breaking cotton clays—vertisols from the Precambrian basement complex dominate the area (Nakileza et al., 1999). Westerhof (2014) states that a region of the nation up to 25 miles broad, along the Uganda-Kenya border, is home to pre-cambrian metamorphic rocks. With the exception of a few isolated granulite areas that are remnants of past metamorphism, these rocks are of the amphibolite metamorphic facies (Westerhof et al., 2014). Planosols, calcic vertisols, and Haplic calcisols, which are of relatively low productivity levels (NEMA, 2010).

3.2.7 Land use activities

The environmental and climatic conditions in the semi-arid Karamoja limit the set of activities undertaken. Approximately 54% of the land area is under wildlife conservation. The population depends largely on agro-pastoralist activities. The study area falls under the pastoral and annual cropping agricultural system (NEMA, 2006/7). The region also hosts major mining centers for marble stones. The Uganda Wildlife Authority (UWA) established and manages Kidepo National Park to the north and three-game reserves including the Matheniko, Bokora Corridor, and Pian

Upe. The wetter part of south Karamoja in Namalu and Iriri supports the growth of crops like maize, millet, sunflower, sweet potatoes, beans, and sim-sim. Mining of marble, gold, and limestone also takes place within the region (Rugadya, 2013).

3.2.8 Population and Ethnicity

Karamoja has a population of approximately 1.1 million people spread over about 27,900 square kilometers, resulting in a density of about 48 persons per square kilometer. The region exhibits significant ethnic diversity, including the Jie, Karamojong, and Tepeth ethnic groups, with minority groups such as the Dodoth, Labor, and Pokot also present (Olum, 2017).

3.3 Research Design

For the socioeconomic aspect of the study, a cross-sectional study design with a quantitative methodology was adopted. This design facilitated the examination of the impact of locust invasions on crop and livestock production and the factors influencing these invasions during a single field visit. While the primary data were gathered quantitatively, qualitative methods were also employed. This dual approach allowed for a comprehensive portrayal of losses attributable to desert locusts.

3.4 Study Population

The study considered the entire population of farmers and families (N) impacted by the desert locust invasion. The research was conducted in the districts of Abim, Amudat, Moroto, and Nakapiripirit. Using multistage sampling, participants were deliberately selected from each district, adhering to administrative boundaries (district > sub-county > parish > village). Specifically, four parishes and two sub-counties were purposefully chosen from each district:

Kakomongole and Moruita (Nakapiripirit)

Rupa and Katikikekile (Moroto)

Loroo and Amudat (Amudat)

Alerek and Magamaga (Abim)

The study population was specifically targeted because it lies along the pathway of the 2020 desert locust swarms that entered Uganda from Kenya (FAO, 2020). In addition to household participants, local council 1 chairpersons, agricultural extension workers, and officers from NGOs were also included in the study.

3.5 Sample Size and Sampling Techniques

Out of the nine districts in Karamoja, four districts were selected based on logistical constraints, security reasons and the presence of locust swarms during the 2020 invasions: Abim, Amudat, Moroto, and Nakapiripirit. A multistage sampling approach was employed at various levels—district, parish, village, and household—utilizing both purposive and random sampling methods.

Purposive sampling was used to select only affected households engaged in both crop husbandry and livestock, ensuring that the sample represented those most affected by the invasions.

Random sampling was employed to select eight villages from the eight parishes. At the village level, six households were randomly selected using a developed registration list with the guidance of local leaders on the characterisation of smallholder farmers.

In total, 192 respondents were targeted for the household survey and 183 households were successfully reached.

Additionally, two Focus Group Discussions (FGDs) were conducted in Moroto and Amudat, involving local council 1 chairpersons, youth, and farmer group leaders. These discussions were

guided by research assistants familiar with local languages to foster trust and encourage open sharing of experiences regarding locust invasions.

Key Informant Interviews (KIIs) were also conducted with resourceful respondents, such as District Production Officers (DPO), Agricultural Officers (AG), and extension workers. These interviews aimed to gain deeper insights into the causes and consequences of desert locust invasions on agricultural production in the affected areas.

3.6 Data collection and analysis

3.6.1 Data collection

The methods used for data collection are as follows:

Household Surveys: Data on episodes of invasions, duration, and determinant drivers of invasions were sourced from households through primary data collection tools. In the sampled areas, 183 household representatives were interviewed in person using a semi-structured questionnaire (Appendix I). The questionnaire primarily consisted of close-ended questions that required respondents to select and/or rank appropriate responses, allowing for rapid quantitative data collection. Although structured questions were preferred to acquire quantitative data, the semi-structured format permitted some flexibility in responses. A field assistant, fluent in the local languages of each district, administered the semi-structured questionnaire following training.

Focus Group Discussions (FGDs):

Two separate FGDs were conducted to collect socioeconomic data from about 15 to 20 members who were randomly selected using field generated small holder registration lists. Composed of youth, elders, local council 1 chairpersons and leaders of farmers' groups in Moroto and Amudat, the FGDs were organized to comply with COVID-19 standard operating procedures limiting the gatherings to essential participants only. Additionally, Moroto and Amudat were chosen

strategically to represent diverse perspectives from distinct areas within the study region, making it unnecessary to hold additional FGDs in each district. The discussions, guided by an FGD guide (Appendix II), allowed free expression, interaction and exchange of views thereby providing rich insights that would have been difficult to capture through structured questions alone. The discussions lasted for 2 hours each.

Satellite Imaging and Remote Sensing:

High-resolution Sentinel 2B satellite images were retrieved from the Copernicus Data Space Ecosystem portal (<https://dataspace.copernicus.eu/>) to assess vegetation health for two seasons: one in the year before the locust invasion (2019) and one during the invasion (2020). Data were collected for two seasonal periods: February to June and July to December, for both 2019 and 2020, to represent seasonal averages in the study area. Each month, two bands (B8 = Near Infrared and B4 = Red) of a single image with less than 30% cloud cover were selected, preprocessed, and processed for Normalized Difference Vegetation Index (NDVI) using the Google Earth Engine (Kumar & Mutanga, 2019) cloud computing environment. For each season, a mean NDVI mosaic was created to represent average vegetation health. NDVI, a common measure of vegetation density and quality, was calculated using the formula:

$$NDVI = \frac{(\text{Near Infrared (NIR)} - \text{Red})}{(\text{Near Infrared (NIR)} + \text{Red})}$$

NDVI values range between -1 and 1, with higher values indicating healthier vegetation. When digital numbers (DN) from satellite or aerial images are used, the calculation method is the same, but the values are scaled according to the DN ranges (Vani & Mandla, 2017).

Random Sampling of NDVI Points: One thousand (1,000) randomly sampled points were generated from the Karamoja region boundary shapefile to extract NDVI values representative of the region. These sampled NDVI values were used to evaluate vegetation changes over time. Data

Analysis: Statistical analyses were conducted to assess changes over time. The household survey responses were coded and analyzed using SPSS program version 23.0.

3.6.2 Data Analysis

3.6.2.1 Desert locust invasion dynamics

Section 2 of the survey questionnaire collected data on desert locust invasion episodes, timing and duration of invasions and the environmental factors that facilitated the invasions. With the use of descriptive, exploratory, and inferential statistics, the collected data was coded and examined. Addition, data collected from interviews and FGDs was used to back up the findings from the quantitative analysis. Descriptive statistical analysis involved determination of counts of responses, and percentages for categorical data and Ch-square analysis to determine the significant drivers of invasions of desert locusts across the study area. The socioeconomic data analysis was complimented with spatial data for vegetation health during the two years (2019 – 2020). Descriptive statistics (mean, standard deviation, min, and max) were used for exploring this data. A paired-sample t-test was used at the inferential level to test whether there were significant differences in the health of the vegetation that influenced the invasion of desert locusts. The comparisons involved two pairs of NDVI values for the months of February-June and July to December 2019 – 2020.

3.6.2.2 Assessing the effects of desert locust invasions on crop and livestock production

Data on questionnaire items on effects on vegetation cover, crop production and livestock production were mainly analysed using descriptive (counts and percentages) techniques. The study further involved analysis of the size (in acres) of land owned by the agropastrolist vis-a-vis size of land used for agriculture during the desert locust year. Minimum, maximum, range, median, mean, standard deviation, Variance, Skewness and Kurtosis statistics were generated to show the

distribution of the results for the effects inflicted on land use for agricultural production. At inferential level, a paired samples t-test procedure was undertaken to determine the difference in vegetation health in the base year and the locust invasion year but also for testing for the differences between land owned and land used for agriculture in the desert locust invasion year. Five pairs were compared based on the individual districts selected and the overall pair of the four districts. The same analysis methods were used to determine whether agricultural production different before and after locust invasions.

3.6.3 Determining the effects of desert locust invasions on small holder farmers household food security and livelihoods

The third section of the questionnaire gathered data on household food security during the locust invasion seasons in the study area. Food security was measured in terms of food items consumed and the number of days they were consumed before and after desert locust invasion. The quantities harvested, bought, consumed, or sold before and after locust invasions. Further, sources of household income and engagement in other non-agricultural livelihoods were assessed for the period of locust invasion. Analysis was done at two levels. At the preliminary stages, it involved the use of descriptive statistics. The association between the locust desert outbreak and the household food security and livelihood concerns of smallholder farmers was examined using a chi-square test. The findings were supplemented with information synthesized from the FGDs. Using paired samples t-test, NDVI for two seasons were compared for the period before locust invasion and that during the locust invasion. Two pairs were compared one for the first season (February - June) and the second for the second season (February – June).

3.6.4 Evaluating the effectiveness of the implemented desert locust control measures in Amudat, Abim, Moroto and Nakapiripirit

Section 4 of the data collection tool gathered data on the desert locust control measures implemented during the 2020 invasions in Karamoja and how effective they were with regard to the timing, place of application, care taken to protect animals and humans, care taken to prevent pollution and the training given to the community to protect themselves against chemical. The measures were evaluated against a four-level scale as not effective, somehow effective, effective and very effective. From this, the responses were coded accordingly and analysis undertaken using descriptive statistics involving generation of frequencies and percentages as well as rankings to reveal the most effective (if any) desert locust control measures undertaken.

CHAPTER FOUR: RESULTS PRESENTATION AND INTERPRETATION

4.0 Introduction

A presentation of the results, analysis and interpretation is given in this chapter following the specific objectives of the study stated in chapter one.

4.1 Desert locust invasions dynamics

4.1.1 Locust invasion timing and duration of events

Analysis of desert locust invasion dynamics results revealed that the locusts (hoppers & mature ones) invaded the Karamoja region during the crop planting and after crop planting seasons (march and May). Subsequent episodes ensued during crop maturation, harvest, and after-harvest seasons (August to October). The first episode found when crop gardens had been planted with maize, beans, green gram, sorghum, and millet in March, April, and May. Moroto and Abim districts were shown to have experienced invasions for the whole cropping season (Table 1), that is March, April, May, and September, October and November. 88% of locust invasions happened right before and right after sowing crops, on average. The percentage of swarms that reached the physiological crop maturity stage was 8.2%. Swarm attacks occurred for one to two weeks, three to four weeks, and two to four months throughout the cropping season of April to June, depending on the stage of locust growth. Adult locust and hopper infestations typically lasted 1-2 weeks and 3-4 weeks, respectively (Table 1). The districts with the highest locust prevalence were Nakapiripirit, Abim, and Moroto. The chi-square results also indicate that the timing and duration of the swarm invasions significantly varied across the four districts (Table 1).

A member during a FGD session reported that “the grasshoppers that landed on trees would last for four to five days and leave after all the leaves are finished. Those that landed in gardens would take between 3 to 4 hours depending on the size of the garden and the swarm. Within a garden, the locusts would take a day. But their duration in the district extended to between two to three weeks as they kept rotating from one area to another”. The members also reported that two waves of invasions were witnessed in the area with the first wave ensuing in March shortly after crop planting and sprouting while the second wave ensued in April, three weeks after the first one. This was after the eggs that had been laid by the mature locusts in the first wave had hatched. According to one member of the focus Group discussion, the area is prepared for planting in March and May, weeding takes place between April and June, and harvesting occurs from August through October every year, which means the invasion corresponded to the crop farming calendar of the agro-pastoralists, with potential to cause adverse negative effects on the sector.

Table 1: Locust invasion timing and duration

Crops grown	Maize, Beans, Peas, Green Gram, Sorghum, Millet, Vegetables, Fruits										Chi-Square	Likelihood	Asymp. Sig.
	Abim		Amudat		Nakapirit		Moroto		Overall				
	No	%	No	%	No	%	No	%	No	%			
Locust invasion by cropping seasonal calendar											113.3	131.8	0.000
Before planting (February)	8	20	44	100	58	100	22	43.1	122	66.7			
After planting (March)	22	55	-	-	-	-	17	33.3	39	21.3			
Sprouting and flowering (May-June)	4	10	-	-	-	-	11	21.6	15	8.2			
At harvest (August)	2	5	-	-	-	-	-	-	2	1.1			
Postharvest	4	10	-	-	-	-	1	2	5	2.7			
Duration of swarm invasion											70.7	77.9	0.000
	No	%	No	%	No	%	No	%	No	%			
1 – 2 weeks	4	10	-	-	19	39.6	23	45.1	36	19.7			
3 – 4 weeks	33	82.5	44	100	28	58.3	2	3.9	128	69.9			
2 months	3	7.5	-	-	1	2.1	3	5.9	6	3.3			
3 months	-	-	-	-	-	-	10	19.6	3	1.6			

4.1.2 Perceived determinants of locust invasions

Results on the determinant conditions that favoured desert locust invasions as perceived by households in the research region are displayed in Table 2. The findings show that favorable rainfall, temperature, wind, soil moisture, and freshness of plants were what drew the swarms. A four-level Linkert scale (least, moderate, favourable, and most favourable) was used to evaluate these factors.

During an interview with one of the district production officers in the locust affected regions, it was pointed out that the locusts were mostly favoured by the state of health of the crops, presence of fruit trees, trees vegetation, grasslands, strong blowing winds, and sandy soil state ($P < 0.05$). Low rainfall and soil moisture were shown as the least favourable factors while surface temperature had a moderate influence on the invasions (Table 2). The results (Figure 1) from the CHIRPS precipitation data analysis also indicate that the amount of rainfall received during locust invasion year were much lower than that of the year before which affirm that the households' perceptions are in line with the science. The findings demonstrate that the research area's vegetation health, wind patterns, and sandy soil type were major factors in the invasion of desert locusts. The results also imply that no single factor but rather a combination and interdependence between them significantly contributed to locust infestations in Karamoja. The Chi-square results indicated that all the factors were significant ($P < 0.01$) determinants of the locust invasion in the study area.

Table 2: Perceived determinants of desert locust outbreaks

	Least favourable		Moderately		Favourable		Most Favourable		Chi-Square	df	Asym p. Sig.
	Obs. N	Residual	Obs. N	Residual	Obs. N	Residual	Obs. N	Residual			
Rainfall	118	72.3	21	-24.8	43	-2.8	1	-44.8	171.426	3	.000
Surface temperature	64	18.3	64	18.3	54	8.3	1	-44.8	59.80	3	.000
Blowing Winds	39	-6.8	43	-2.8	94	48.3	7	-38.8	84.869	3	.000
Soil moisture	95	49.3	27	-18.8	59	13.3	2	-43.8	106.377	3	.000
Soil type (Sandy)	84	38.3	33	-12.8	63	17.3	3	-42.8	81.984	3	.000
Vegetation health	33	-12.8	34	-11.8	107	61.3	9	-36.8	118.093	3	.000

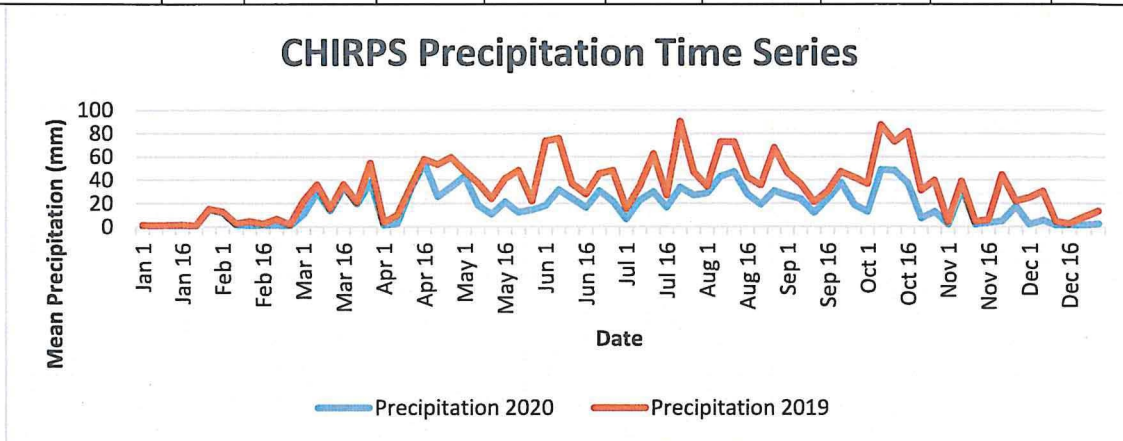


Figure 3: Rainfall amounts in the study area for 2019 and 2020

4.2 Effects of desert locust invasion on crop and livestock production in Karamoja

Results in Table 3 show the effects the of desert locust invasion on vegetation in Karamoja. They show that locusts mostly reduced tree and grass cover and the least effect was an increase in bare grounds. In crop production, the invasions mainly accounted for increased costs of planting after devouring previously planted crops followed by interference with the sprouting and flowering of already planted crops. The least of the effects on crop production were reduced crop harvest and reduced shade and garden windbreakers. In livestock production, the locust invasions majorly reduced pastureland followed by movement for long distances to search for pasture. The least effects were an increase in livestock diseases and reduced milk yield.

Table 3: Effects of locust invasion on vegetation, crop, and livestock production

Effects on;	N	%
Vegetation cover		
Reduced tree cover	76	43
Reduced grass cover	70	39
Increased bare ground	33	18
Crop production		
Increased costs of replanting	39	28.3
Interfered with crop sprouting/flowering	36	26
Interfered with the planting calendar	33	24
Reduced shade and garden windbreakers	20	14.5
Reduced crop harvest	10	7.2
Livestock production		
Reduced pasture land	66	38.4

Effects on;	N	%
Long distances to find pasture	54	31.4
Increased Livestock diseases	28	16.2
Reduced milk yield	24	14

The results in Table 3 imply that the effects of desert locusts were mostly witnessed in livestock production as compared to arable farming. The locusts consumed vegetation of all forms, feeding on leaves, tree nodes, and shoots. Mature locusts anchored on trees affected their growth. The young locust bands on the other hand anchored on grass vegetation which was pasture for livestock and cleared such fields which implies that livestock was unable to access enough feeds. This prompted long-distance movements by agro-pastoralists to access pasture for the livestock thus making the livestock vulnerable to livestock diseases and vectors. From diseased livestock came low yields in terms of meat, milk, and sale value.

From the descriptive statistics of the NDVI data, the results (Table 4.5 & Figure 4.2) reveal 0.2 and 0.3 mean NDVI values for 2019 and 2020 respectively for the first season (February to June). For each of the two years, the standard deviation from the mean was ± 0.1 . For the second season (July to December), the mean NDVI was $0.34(\pm 0.06)$ and $0.31(\pm 0.54)$ for 2019 and 2020. The mean NDVI was higher in 2020's first season, based on these results. However, in the second season, the mean NDVI for 2020 was lower than that for 2019. The paired-sample t-test results show a negative mean difference between NDVI for 2019 and 2020 during the first season and a positive mean difference for the second season for the comparison years. The differences in the means are also shown to be significant for the two time periods. These results reveal that NDVI for the second season of the locust year significantly reduced compared to that of 2019 for the same season. This means that the greatest impact of locusts on vegetation was in the second season

of 2020.

Table 4: Descriptive statistics of NDVI and paired samples T test for differences in vegetation (NDVI) between 2019 and 2020

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Feb - June	2019	1000	.186678547	.0586735000	.0018554190	.183037582	.190319513	.0559756	.4547150
	2020	1000	.30286864	.069551688	.002199418	.29855263	.30718464	.110930	.516479
July - Dec	2019	1000	0.34885453	.061306073	.001938668	.34505020	.35265885	.162368	.522686
	2020	1000	0.31280526	.054928933	.001737005	.30939666	.31621385	.178509	.571702
Pairs	Comparison		Mean difference	Std. Dev.	Std. error t	df	Sig. (2-tailed)		

Pair 1 -	NDVI Feb -Jun -						
	2019: NDVI Feb -	.1161900	.06009825	.00190047	-61.137	999	.000
	Jun 2020	888	88	38			
Pair 2-	NDVI July -Dec						
	2019: NDVI July -	.0360492	.05710005	.00180566	19.965	999	.000
	Dec 2020	70	4	2			

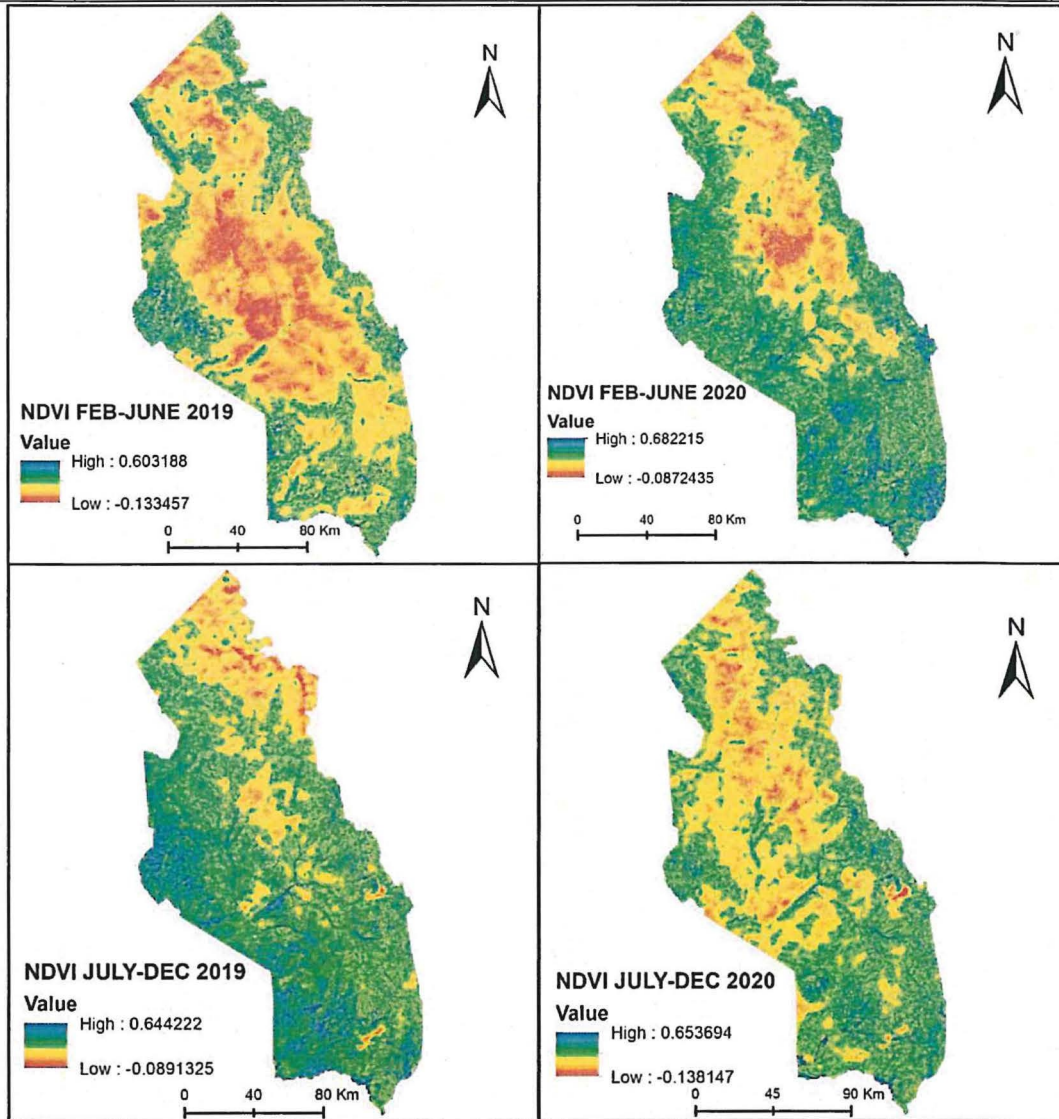


Figure 4: Mean NDVI tiles of the study area for February -June and July -December 2019&2020

Beyond that revealed in the key informant interviews was that desert locust invasions affected agricultural production in the form of loss of household incomes, interference with crop growing cycles, and reduction in farm harvest.

In a FGD session, a member retaliated, “the locust cleared all the grass that our cattle used to feed on and the tree leaves that our camels used to rely on. Only the harder parts that fell off after hoppers had finished the leaves is what the goats would eat which was not enough to satisfy them. For the crop that had sprouted, the effect was worse because no leaf was left after the swarms occupied the gardens”.



Figure 5: FGD session with small holder farmers in Amudat district, TC (source: field survey 2021)

To determine the impact of the invasions on agricultural usage and productivity, the study also contrasted the area of land held by agropastoral households with what was utilized during the year of the desert locust invasions. The findings (Table 5) indicate that during the desert locust invasion period, a household might own up to 25 acres of land, of which 15 acres were used for agriculture. Every household possessed about 34 acres of land on average, of which 3 acres were used on average during Karamoja's locust invasion season. This indicates that, in comparison to the land possessed by the agropastoralists, households in the study area used 74% less land during the season of the desert locust invasion.

Table 5: Land owned and used during

Measure	Land owned (acres)	Land Used (acres)
Minimum	1	1
Maximum	25	15
Range	24	14
Median	3	2
Mean	3.9	2.9
Std. Deviation	2.9	1.8
Variance	8.1	3.1
Skewness	3.1	2.4
Kurtosis	17.1	11.6

The paired t-test analysis of the comparison of the significance of the differences between land owned and land utilized for agriculture during desert locust invasions also shows that the differences were significant ($P < 0.001$) for the districts of Amudat, Nakapiripiriti, and Moroto but

insignificant ($P > 0.05$) for Abim district (Table 6). This means that for the former districts, sizeable land (> 1 acre) was not put to use during the locust invasion season, and for the latter district (Abim), about the same size of land was put to use for agriculture. The results indicate that desert locusts affected agricultural production by discouraging investment in agriculture. This implies that agropastoralists also worked in trade/business, mining, and other non-farm activities. The results could also imply that not all the land that is owned by agropastoralists in the Karamoja is suitable for farming activities given the harsh nature of the environment associated with arid conditions.

Table 6: Paired samples T test for differences in land owned and land used (by district and overall)

Pairs	Comparison	Mean	Std. Dev.	Std. error	t	df	Sig. (2-tailed)	Correlation	Corr. sig
Pair 1 - Abim	Land owned Land used during the locust year	2.825	4.126	.652	4.331	39	.000	.205	.204
Pair 2- Amudat	Land owned Land used during the locust year	.114	.321	.048	2.348	43	.024	.907	.000
Pair 3- Moroto	Land owned Land used during the locust year	.225	1.230	.172	1.309	50	.196	.468	.001
Pair 4- Nakapir ipirit	Land owned Land used during the locust year	.979	1.537	.222	4.415	47	.000	.814	.000
Pair 5 – All districts	Land owned Land used during the locust year	.964	1.537	.178	5.424	182	.000	.542	.000

4.1.2 Effects of desert locust invasion on household food availability, consumption, and purchases

Food stuffs that were mostly consumed before the desert locust invasions were grains such as millet, maize, and cereals including beans, green gram, and peas, followed by root tubers and

vegetables. These were consumed for more than 10 days in a month before locust invasions (Table 7). The least consumed food items before the invasions included fruits, meat, pork, sugar and poultry products, ground and cashew nuts, vegetables, and milk products. These were eaten, on average, for less than 10 days a month before the desert locust invasions.

Table 7: Frequency of food items consumed by interviewed households before locust invasion

	Maize & maize porrid ge	Millet grain	Roots & tubers	Sugar/p roducts	Beans & peas	G & cashe w nuts	Vegeta bles	Fruits	Meat & pork	Poul try, prod ucts	Milk /pro duct s
Minimum	1	1	1	0	0	0	0	0	0	0	0
Maximum	100	180	150	30	200	60	110	14	30	50	70
Range	99	179	149	30	200	60	110	14	30	50	70
Median	4	4	2	3	4	3	3	2	2	3	4
Mean	15	18	13	4	15	4	10	2	3	3	6
Std. Deviation	26	38	27	5	33	8	20	2	3	5	10
Variance	662	1437	752	25	1090	57	419	3	10	21	93
Skewness	2.3	3	3	3.2	3.2	6	4	3	5	7	4
Kurtosis	4	8	13	13	11	37	12.3	19	34	66.1	18.3

The number of days that people consumed staple foods reduced during invasions by desert locusts.

The findings (Table 8) show that after the invasion of the desert locust, the same foods were still consumed, but in smaller quantities as shown by the number of days they were consumed. Sorghum, millet, maize, beans and peas, and roots and tubers were the dominant foodstuffs consumed for five or more days on average but less than 10 days in a month. However, vegetables, that had been in the most consumed items category completely reduced, which implies that these were the crops affected most by locust plagues. The results also show that after the invasions, households increased uptake of sugar/sugar products, implying that they possibly relied more on tea to cope with the reduced food quantities from farms. The food items that were critically reduced to less than 5 days a month on average included those that were not regularly consumed before the invasions. These are vegetables fruits, meat and pork, poultry and milk products.

Table 8: Number of days selected food items were consumed by interviewed household households after locust invasion

Statistics	Maize & maize porridge	Other cereals - rice, sorghu, m, Millet	Roots & tubers	Sugar/p roducts	Beans & peas	G & cashew nuts	& Veget ables	Fruits	Meat & pork	Poultry , produc ts	Milk/ produ cts
Minimum	0	0	0	0	0	0	0	0	0	0	0
Maximum	75	100	120	125	80	40	100	30	13	12	14
Range	75	100	120	125	80	40	100	30	13	12	14
Median	2	2	1	2	3	2	1	1	1	1	2
Mean	7	9	5	7	6	4	3	1	1	2	2
Std. Deviation	13	17	12	14.4	12	7	10	3	2	2	2
Variance	172	283	154	207	136	46	94	7	3	3	4
Skewness	3.4	3.1	6	5	4	3.3	7.4	8.2	5	4	3.2
Kurtosis	13.2	11	44.3	29	21.3	12	63.3	84	25	16.4	15

The key informants revealed that the desert locust invasion was unprecedented and their effect was mainly seen in terms of delayed planting, food insecurity, crop yield loss, stunted growth, and farm residual loss. A member during one of the FGD meetings also reported that “we have been suffering from famine ever since the locusts came to our area in 2020. Poverty levels increased

and some people were forced to migrate with their animals to south Karamoja in anticipation of finding grass because the locusts had eaten up all the grass in our area”.

The t-test results (Table 9) reveal that with the exception of peanuts and cashew nuts, there were notable variations in the staple foods consumed throughout the day before and after the locust invasion. The conclusion is that, in the chosen study district, locust invasion had a significant ($P < 0.05$) impact on household food security. As the number of days that food was consumed generally decreased following the locust invasion, the effect was primarily negative. The results indicate a higher number of days of staple food crops consumption before desert locusts invaded the region but reduced after the invasions implying that the invasions reduced the amount of food available for household consumption after they devoured crop fields.

Table 9: T: Paired-Samples T Test comparing the frequency of food items consumption before and after locust invasion.

	Number of days;	Mean	Std. Dev.	Std. error	t	df	Sig. (2-tailed)
Pair 1	Maize/maize porridge was consumed before locust season. Maize/maize porridge was consumed after locust season.	8.5	17.7	1.3	6.5	182	.000
Pair 2	Other cereal (rice, sorghum, millet, bread, pasta etc.) were consumed before locust season. Other cereal (rice, sorghum, millet, bread, pasta etc.) were consumed after locust season.	9.4	26.9	1.9	4.7	182	.000
Pair 3	Roots and tubers (cassava, Irish potatoes, sweet were consumed before locust season. Roots and tubers (cassava, Irish potatoes, sweet were consumed after locust season.	8.0	20.9	1.5	5.2	182	.000
Pair 4	Sugar or sugar products were consumed before locust season. Sugar or sugar products were consumed after locust season.	-2.8	13.1	.97	-2.9	182	.004
Pair 5	Beans and peas were consumed before locust season. Beans and peas were consumed after locust season.	8.7	27.9	2	4.2	182	.000

Pair 6	Groundnuts or cashew nuts were consumed before locust season.	-13	6.05	.45	-.28	182	.779
	Groundnuts or cashew nuts were consumed after locust season.						
Pair 7	Vegetables were consumed before locust season.	6.8	16.3	1.2	5.6	182	.000
	Vegetables were consumed after locust season.						
Pair 8	Fruits were consumed before locust season.	.62	2.9	.2	2.9	182	.003
	Fruits were consumed after locust season.						
Pair 9	Goat or other red meat and pork were consumed before locust season.	1.4	2.8	.2	6.9	182	.000
	Beef, goat or other red meat and pork were consumed after locust season.						
Pair 10	Poultry and eggs were consumed before locust season.	1.3	4.5	0.3	3.9	182	.000
	Poultry and eggs were consumed after locust season.						
Pair 11	No of days milk/yoghurt were consumed before locust season	3.9	9.7	.7	5.6	182	.000
	No of milk/yoghurt were consumed after locust season						

Analysis was also conducted on the number of months of dependence on food purchases during the locust year. The results (Table 10) show that the households in Karamoja depended on food purchases for a full month on average. For some households, food purchases went on as long as

four months. The reasons advanced for buying was due to the fact that the households did not produce enough of the specific food items that they bought. This means that desert locusts invasions reduced amount of food harvested and available for household consumption thus calling for external sourcing through buying which also reduced on household income from past savings and, or other sources.

Table 10:Duration of Household reliance on food purchase during the locust invasion

Description	Statistics
Minimum	1
Maximum	4
Range	3
Median	1
Mean	1
Std. Deviation	.454
Variance	.206
Skewness	6.1
Kurtosis	38.6

4.3 Locust control measures implemented during the 2020 invasions and their effectiveness in Karamoja

Government and the affected communities in the study area undertook several measures to combat desert locusts and prevent them from spreading further. Effectiveness in this study, refers to the measures that were able to kill locusts along their life cycle (all the stages) and also reduce their impacts and the possibility of further invasions. These included aerial and ground spraying of

locusts with chemicals, trampling on hoppers, digging up egg pods, chasing locusts, and burning straw (Table 11). Ground and aerial spraying were rated as effective and very effective respectively by the households interviewed respondents. Chasing of locusts, and burning straw were rated somehow effective while digging trenches, trampling on hoppers and lighting of bush-fires were rated as not effective. These results mean that whereas several methods were used in desert locust control, only 20% of them were effective in managing desert locusts. This points towards the unreadiness of the country to focus on locust management. Since most of the ineffective measures were community initiatives, it implies that the communities have not developed resilience to the desert locust invasions. The most effective measures involving spraying are out of reach to agropastoral communities where farmers' illiteracy in the use of agricultural chemicals in pest management is highest. The results from an FGD however showed that none of the implemented measures was successful. In the FGD, a member stated, "No measure was effective because the locusts would only move after eating up and finishing the vegetation or when the wind blew them away. Even when people would drum and make the loudest noise with the drumming of Jerri cans, the locust would not leave before finishing to eat all the leaves on the vegetation. Where burning was applied, only a few bands would be killed and more would just keep coming in. They kept laying eggs which culminated into the second wave".

Table 11: Effectiveness of the locust management measures implemented

Measures	Somewhat				Very effective			
	Not effective		effective		Effective			
	No	%	No	%	No	%	No	%
Aerial spraying	14	7.7	19	10.4	97	53	53	29
Ground spraying	4	2.2	29	15.8	26	14.2	124	67.8
Smoking/lighting bush-fire	32	17.5	118	64.5	30	16.4	3	1.6
Digging trenches	43	23.5	128	69.9	9	4.6	3	1.6
Making loud noise	17	9.3	140	76.5	20	10.9	6	3.3
Trampling on hoppers	40	21.9	125	68.3	16	8.7	2	1.1
Chasing locusts	20	10.9	122	66.7	34	18.6	7	3.8
Digging up egg pods	21	11.5	135	73.8	24	13.1	3	1.6
Roosting/burning straw	17	9.3	140	76.5	20	10.9	6	3.3

The study also assessed the effectiveness of the implemented measure in terms place of application, protection to animals, and training and chemicals use. The results (Table 14) show that place of application, was the most effective (41.5%) followed by chemicals used (33.9%), and the method of application (ground and aerial spraying) with 31.7%. Whereas the least effective was for care to protect animals and humans (17.5%) followed by regard for pollution avoidance (18%) and then community training on the use of the control measures (23%). These results signify that much more attention was given to the elimination of desert locust invasions but less on care and protection of the environment, animals and the humans. It means the measures implemented would result into other challenges that call for future planning in the management of desert locusts.

Table 14: Effectiveness of measures regarding mode of application, protection to animals, training, and chemicals used.

	Not effective		Somehow effective		Effective	
	N	%	N	%	N	%
Place of application	13	7.1	94	51.4	76	41.5
Method of application	43	23.5	82	44.8	58	31.7
Care to protect animals & Humans	82	44.8	69	37.7	32	17.5
What pollutions avoidance	59	32.2	91	49.7	33	18
Training to the community	61	33.3	80	43.7	42	23
Effectiveness of chemical used	16	8.7	105	57.4	62	33.9

CHAPTER FIVE: DISCUSSION

5.1 Introduction

This section analyzes the findings in comparison with the outcomes of previous research conducted on related topics. It examines how the current results align with or differ from existing literature and contributes to the broader understanding of the subject matter.

5.1.1 Locust invasion dynamics and determinant factors

The 2020 desert locust invasions in Amudat, Abim, Moroto and Nakapiripirit lasted between 2 weeks and 1 month and there were several waves that ensued at intervals following the weather patterns and vegetation conditions. As stated by Hunter (2019), locust populations can range from very low (during recessions) to very high (during plagues). Locusts are widely dispersed whereas populations are low, but when conditions are suitable, populations rise and the dispersed locusts adapt their behaviour, resulting in their congregating in bands and swarms.

The year 2020 saw a rise in desert locust invasions in Amudat, Abim, Moroto, and Nakapiripirit due to optimum weather (rainfall) and vegetation conditions. Crop planting and sprouting corresponded to the onset of the single rainfall season in Amudat, Abim, Moroto, and Nakapiripirit. This fueled the locust invasion. As the rains create other environmental conditions ideal for the desert locust's growth and development, maturation, and its gregarization concentration, and migration, the onset of the rains here significantly transforms the landscape (Peng et al., 2020). While the season's winds facilitate the migration of grown-up swarms, desert locust reproduction profits from the rise in soil/sand wetness and freshness of vegetation during the rainy season. Within the East African region, rainfall and land cover data have been used to predict desert locust invasion scenarios with a high degree of certainty (Veran et al., 2015). Inverse

conditions in the initial epicenters are necessary for these predictions to prove accurate, though. The following year, as conditions in West Asia and Northeast Africa shifted, the desert locusts moved there as well. The 2018's heavy precipitation episodes on the Arabian Peninsula produced enough soil moisture and lush vegetation to facilitate the invasion of the peninsula (Wang et al., 2021). Temperature and the leaf area index have a major effect on the desert locust invasion location according to Chen et al. (2020).

The factors that drive these pests to migrate from their original breeding locations are typically compatible with the requirements for inhabitation and breeding in the migratory destinations. This is because the locusts that invade East Africa can be traced back to the Arabian Desert (Wang et al., 2021). In order to anticipate invasions and plan for the deployment of preventive measures in advance, management strategies for desert locusts should take this into account during monitoring and surveying efforts. This study demonstrates how crucial it is to remember that environmental conditions, the stage of locust growth, and the distance from the Kenyan border (epicentre) all influenced the locust lengths. The length of the locust's invasion also had a significant impact on the pace of vegetation consumption, damage, and reproduction, all of which had an impact on the wellbeing of natural ecosystems and food production systems.

5.1.2 Effects of locust invasions on crop and livestock production in Amudat, Abim, Moroto and Nakapiripirit

Contrary to the exaggerated fears of a large impact, the results of the current study show that the 2020 desert locust invasion of Amudat, Abim, Moroto, and Nakapiripirit had minimal effect on the natural cover. This indicates that environmental factors, as well as interventions (chemical spraying), caused the migratory locust swarms that reached Amudat, Abim, Moroto, and Nakapiripirit from western Kenya, but never gave them enough time to breed and gregarize before

leaving (FAO 2020). During invasions, mature, highly dense locusts cause the most harm to crops and surrounding vegetation (Chapuis et al., 2020). The non-occurrence of such a scenario in the current study area implies that the swarms that made it to Uganda were either weak or low density, having either been scattered by chemical spraying in Western Kenya or having had their feeding habits disrupted, causing them to travel great distances without stopping to feed on host vegetation. The results somewhat contradict those of Wang et al. (2021), who contended that heavy rainfall and newly emerging vegetation influenced locust invasion scenarios in the Arabian Peninsula, West Asia, and Northeast Africa. These conditions allowed locusts to breed, multiply, and gregarize, causing significant damage to the vegetation cover.

According to the social-economic data collected, the locust swarms that occurred in 2020 in areas such as Amudat, Abim, Moroto, and Nakapiripirit caused more harm to natural vegetation cover such as grasslands and trees as compared to crop output. It is important to note that most of the communities in these areas are pastoralists who rely heavily on grasslands for livestock grazing. The reduced grass and tree cover due to the locust invasion may limit their access to sufficient livestock feeds, which can potentially hinder the increase of meat and milk yield. The depletion of vegetation cover has resulted in pastoralists having to travel long distances with their livestock, leading to territorial disputes and distancing from livestock production facilities (Loupa 2019). Despite the alert issued during the 2020 locust invasion, swarms continued to reproduce and expand deeper into East Africa from the Arabian Peninsula, causing extensive damage to crops (FAO 2020). A recent report showed that in Amudat, Abim, Moroto, and Nakapiripirit, 21% of households experienced damage to their croplands due to the 2020 locusts. However, it's worth noting that this study was conducted in an area where crop production is not the primary agricultural activity. Instead, pastoralism is the main source of livelihood for local communities,

as documented by Nakalembe et al. in 2017. The locusts primarily damaged natural vegetation, which was abundant at the time of the invasion. This finding aligns with the FAO's report from 2020, which stated that the locusts mainly affected grazing lands in the Lango sub-region, followed by Karamoja and Acholi.

5.1.3 Effect of desert locust invasion on livelihoods of agropastoral in Amudat, Abim, Moroto and Nakapiripirit

The study revealed that desert locusts affected incomes, food supply, and the general livelihoods of agropastoral in Amudat, Abim, Moroto and Nakapiripirit. The results are similar to those by Hunter (2019) makes an argument that dense bands and swarms of locusts may severely impact pastures and crops because they travel and suddenly appear in enormous numbers in places that have not been invaded, overpowering local crop protection initiatives. Hunter (2019) asserts that to minimize the scope of swarm invasions, governments should implement locust management initiatives and halt their advance into cropping areas. This is because heavy dependence on crop and livestock production by most sub-Saharan countries and thus these suggestions are meant to safeguard such livelihoods. In Uganda, FAO (2020) report shows that the locusts invaded communities that derive their livelihoods, mainly from crop production and from livestock production.

According to a review by Le Gall et al. (2019a), grazing as a land management method has ecological feedbacks on locust populations, which alter food security in remote locations since locusts can migrate. It is worthwhile to note the current study area is largely grazed on a communal basis but also neighbors an equally related pastoral lands on the western parts of Kenya. Therefore, the results that agropastoralists livelihoods were the most affected during the 2020 locust invasion in Amudat, Abim, Moroto and Nakapiripirit. This is also similar to the findings by FAO (2020b)

where 58% of the households in Karamoja reported to have become food insecure during the 2020 locust invasions of the region. In these households, stocked foods declined and the number of meals reduced tremendously just like what the current study found out.

5.1.4 Desert locust control measures and their effectiveness

Control and management techniques for desert locusts have developed for areas of the planet that are periodically overrun by these migratory pests. Since invasion cases in Uganda's Amudat, Abim, Moroto, and Nakapiripirit areas have been irregular and intermittent, the majority of the measures put in place are curative. As a result, the most popular methods of controlling the 2020 locust invasion involved spraying chemicals and pesticides both above and below the earth. Chemicals and early-stage spraying for developing hoppers can be more effective when managing an outbreak (Showler et al. 2021). Although the study's findings demonstrate how successful aerial and ground spraying was, the measures taken hurt the natural environment (Zhang et al. 2019). The country needs to enhance its capacity for forecasting desert invasions both now and in the future, as well as arrange for proactive care to lessen the need for chemical use, which would otherwise be the only effective defense against invasions. Showler et al. (2021) argue that despite the fact that chemical spraying may be helpful for minimizing the propagation of locust swarm status, the expenses and disruptions connected with it undercut the advantages. The majority of locust control programs, according to Hunter (2019), focus on routinely tracking the locusts and initiating treatment programs upon finding bands or swarms. However, combining these early intervention efforts with a thorough knowledge of the variables contributing to a rise in locust population and areas where locusts are most likely to be found will increase the likelihood of success. The goal of the rapid detection and treatment of as many locusts as feasible in each generation of rise is to

implement a preventive control approach. By slowing the rate of growth in each generation, these treatments can lessen the harm that locusts cause when they infest crops.

The huge management cost of the 2020 desert locust invasion in Uganda, which required borrowing up to \$4 million, was one of the primary issues of controversy. Hunter (2019) points out that numerous chemical pesticides have been used in treatment methods and will continue to be used. However, with increasing restrictions on the use of chemical pesticides, alternative approaches must be investigated as part of treatment programs to guarantee that locusts are treated whenever and wherever they are identified. Even though using chemicals would be less expensive, more money is spent on surveillance and waiting until locust swarms arrive before intervening. The study's findings also indicated a limited usage of biological control methods, such as the employment of microbes, insects, and birds, which Peng et al. (2020) contend have the ability to lessen outbreaks while minimizing adverse effects on the ecosystem and agriculture. Given the high rates of illiteracy in the study area and the fact that these techniques call for specialized training, it is assumed that their usage will be restricted. Peng et al. (2020) claim that while green technologies such as light and sound stimulation also appear to function well, their widespread adoption will be difficult and require technological advances like remote sensing and modelling.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The current investigation applied household survey and FGDs to collect that for analysis of desert locust invasion events, duration and determinants and associated damages to crop and livestock production in addition to assessing the effectiveness of the employed control measures. As such the following conclusions were drawn:

The results showed that the desert locusts stayed between 2 weeks and 1 month in the invaded areas. Their invasion and stay mainly attributed to vegetation freshness and climate related factors, with insignificant variation across the region.

The findings also revealed that the invasion of desert locusts in Amudat, Abim, Moroto and Nakapiripirit had significant impact on grassland and tree cover. However, minimal changes in crop/farmlands were registered.

The invasion of the desert locusts significantly affected food consumption in the affected households since less was food produced during the invasion period as compared to before the invasion. This forced households to make food purchases to supplement farm harvest. This together with the cost of replanting adversely affected the incomes of households.

Basing on the attention and pain created by the invasion of the desert, the study revealed that the invaded communities were ill prepared to handle and manage the locusts and the damages caused thereof. The risk-reduction strategies put in place during the locust invasion were subsequently primarily reactive, exceptionally costly, and had detrimental effects on the environment.

6.2 Recommendations

Due to the high vulnerability of the entire North eastern region of Uganda to desert locusts, there is need to employ geospatial data and ground surveys to identify and promptly notify the various stakeholders to manage the invasions.

Findings from this study should help the United Nations institutions like the World Food Programme (WFP), FAO, government and non-government institutions in supporting the affected population to better prepare for disasters, extend food support and /or agricultural investment for better livelihood.

Planning for locust crisis management should also concentrate on strengthening the National locust control units so that they can better prepare for future surges and provide more efficient management. Additionally, rather than relying just on therapeutic interventions with few options, local communities must be allowed to implement preventive actions.

REFERENCES

- Akabwai, D. M. O., & Ateyo, P. E. (2007). The realities of cattle raids in Karamoja: A report on the findings of the field assessment in Karamoja. *Journal of Pastoral Development*, 5(2), 83–91.
- Chapuis, M. P., Raynal, L., Plantamp, C., Meynard, C. N., Blondin, L., Marin, J. M., & Estoup, A. (2020). A young age of subspecific divergence in the desert locust inferred by ABC random forest. *Molecular Ecology*, 29(23), 4542–4558. <https://doi.org/10.1111/mec.15663>
- Chen, C., Qian, J., Chen, X., Hu, Z., Sun, J., Wei, S., & Xu, K. (2020). Geographic distribution of desert locusts in Africa, Asia and Europe using multiple sources of remote-sensing data. *Remote Sensing*, 12(21), 1–14. <https://doi.org/10.3390/rs12213593>
- Chen, H., Cressman, K., Kramer, K., & Tonnang, H. E. (2020). Early warning systems for Desert Locust invasions: The FAO experience. *Pest Management Science*, 76(5), 1421–1429. <https://doi.org/10.1002/ps.5718>
- Cisse, S., Ghaout, S., Mazih, A., Babah Ebbe, M. A. O., Benahi, A. S., & Piou, C. (2013). Effect of vegetation on density thresholds of adult desert locust gregarization from survey data in Mauritania. *Entomologia Experimentalis et Applicata*, 149(2), 159–165. <https://doi.org/10.1111/eea.12121>
- Cisse, S., Mounir, B., & Abderrahmane, B. (2013). Impact of vegetation cover on Desert Locust gregarization: Effects of locust density and vegetation condition. *Journal of Arid Environments*, 98, 62–70. <https://doi.org/10.1016/j.jaridenv.2013.09.003>
- Cressman, K., & Fresco, L. O. (2001). Desert Locust Guidelines 3. Information and forecasting.

Cressman, K. (1996). Monitoring desert locusts in the Middle East: An integrated approach. *Bulletin of Entomological Research*, 86(5), 501–506. <https://doi.org/10.1017/S0007485300050074>

Cressman, K. (2017). Desert locust guidelines: A guide to effective control. Food and Agriculture Organization of the United Nations. <http://www.fao.org/3/i8056e/i8056e.pdf>

Cressman, K., & Fresco, L. O. (2001). Desert locusts: System dynamics of crop protection in the Sahel. *Journal of Applied Ecology*, 38(4), 787–798. <https://doi.org/10.1046/j.1365-2664.2001.00622.x>

Cressman, Keith. (2013). Role of remote sensing in desert locust early warning. *Journal of Applied Remote Sensing*, 7(1), 075098. <https://doi.org/10.1117/1.jrs.7.075098>

Dyer, E., Kansiime, F., Ntawuhiganayo, J., & Marichal, R. (2008). Ecology and conservation of the Karamoja ecosystem. Karamoja Wildlife Research Centre.

Egeru, A. et al. (n.d.). Egeru_past present and future climate trends under varied representative concentration pathways for a sub humid region in Uganda.

Egeru, A., Katerega, E., & Majaliwa, M. J. G. (2015). Karamoja's vegetation and soils: A focus on sustainable agricultural productivity. Uganda National Research Repository.

Egeru, A., Majaliwa, J. G. M., Isubikalu, P., & Mafabi, M. (2014). Pasture dynamics in the Karamoja sub-region of Uganda. *Journal of Arid Environments*, 106, 26–35. <https://doi.org/10.1016/j.jaridenv.2014.02.004>

Endris, E. (2021). COVID-19, locust invasions, and flood events: Compounded impacts on food security in East Africa. *African Journal of Agricultural and Resource Economics*, 16(1), 33–47. <https://doi.org/10.1108/9781839095740-012>

FAO, AGRICULTURE, E. M. O., FEWSNET, WFP, & PARTNERS, S. T. C. (2020). Impact of Desert Locust Infestation on Household Livelihoods and Food Security in Ethiopia Joint Assessment Findings. *Joint Assessment Findings*, April, 1–14.

FAO. (2020). Assessment of the impacts of desert locusts in East Africa: A case study in Ethiopia, Kenya, Somalia, and Uganda. Food and Agriculture Organization of the United Nations, Rome.

FAO. (2020). Locust swarm in east Africa could be a castastrophe.

Food and Agriculture Organization (FAO). (2020a). Desert locust invasion and its effects on crop and livestock production in East Africa. Food and Agriculture Organization of the United Nations

Food and Agriculture Organization (FAO). (2020b). Report on food security in Karamoja during the 2020 desert locust invasions. Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization of the United Nations (FAO). (2020). Desert Locust upsurge: East Africa situation update. Retrieved from <http://www.fao.org/ag/locusts>

Food and Agriculture Organization. (2020). Desert locust crisis: Appeal for rapid response and sustained action. Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization. (2020). Locust invasion and its impact on the vegetation in Uganda. FAO.

Geng, Y., Dong, Y., Zhao, L., Huang, W., Ruan, C., Zhang, H., & Zhang, B. (2018). Desert locust plague monitoring using time series satellite data. *International Journal of Precision*

Agricultural Aviation, 1(1), 24–30. <https://doi.org/10.33440/j.ijpaa.20200304.111>

Githae, E. (2021). Traditional and modern strategies for managing desert locust invasions in East Africa. *Journal of Sustainable Agriculture*, 20(3), 245–255. <https://doi.org/10.1111/josa.2021.245>

Githae, E. W. (2021). Biological control of desert locust (*Schistocerca gregaria* Forskål). *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, 16(013). <https://doi.org/10.1079/pavsnr202116013>

Gobron, N., Pinty, B., Verstraete, M. M., & Govaerts, Y. (2000). Advanced vegetation indices optimized for up-coming sensors: Design, performance, and applications. *IEEE Transactions on Geoscience and Remote Sensing*, 38(6), 2489–2505. <https://doi.org/10.1109/36.885202>

Gómez, C., Hill, M., & Dorn, S. (2019). Human civilizations and pest invasions: Locust plagues as an ancient problem. *Environmental History*, 24(3), 458–477. <https://doi.org/10.1093/envhis/emz027>

Hmimina, G., Dufrêne, E., Pontailleur, J. Y., Delpierre, N., Aubinet, M., Caquet, B., de Grandcourt, A., Burban, B., Flechard, C., Granier, A., Gross, P., Heinesch, B., Longdoz, B., Moureaux, C., Ourcival, J. M., Rambal, S., Saint André, L., & Soudani, K. (2013). Evaluation of the potential of MODIS satellite data to predict vegetation phenology in different biomes: An investigation using ground-based NDVI measurements. *Remote Sensing of Environment*, 132, 145–158. <https://doi.org/10.1016/j.rse.2013.01.010>

Hunter, D. M. (2019). The future of locust control: New technologies in pest management. *Current Opinion in Insect Science*, 34, 79–84. <https://doi.org/10.1016/j.cois.2019.03.010>

Ingutia, R., & Sumelius, J. (2022). The multifaceted dimensions of food security: A study in hazard-prone regions. *Food Security Journal*, 14(2), 197–211. <https://doi.org/10.1007/s12571-022-01234-x>

Islam, M. S., Roessingh, P., & Simpson, S. J. (1994). Parental effects on the behavior and coloration of nymphs of the desert locust. *Journal of Insect Physiology*, 40(2), 173-181. [https://doi.org/10.1016/0022-1910\(94\)90120-1](https://doi.org/10.1016/0022-1910(94)90120-1)

Jhiknaria, H. (2021). Distribution of Desert Locust *Schistocerca gregaria* in Rajasthan , India and Establishing an Early Warning System for Locust Control in India. 0–81.

Jhiknaria, P. (2021). Migration patterns and environmental determinants of locust swarms in Asia and Australia. *Asian Journal of Environmental Science*, 12(4), 256–265. <https://doi.org/10.1007/s12345-021-7890-6>

Joshi, R., Kamaraju, D., & Siddiqui, Q. (2020). Swarming behavior of locusts in the Acrididae family. *Entomological Review*, 100(1), 67–75. <https://doi.org/10.1134/S0013873820010033>

Kassa, H., Tesfaye, H., & Gelaye, K. (2020). The role of community participation in the management of desert locusts: Insights from Ethiopia. *Journal of Agricultural Sciences*, 15(2), 149-160. <https://doi.org/10.5539/jas.v15n2p149>

Kassegn, A., & Endris, E. (2021). Desert locust invasions and food security: The case of East Africa. *Journal of Food Security*, 9(3), 103–110. <https://doi.org/10.12691/jfs-9-3-3>

Kassegn, A., & Endris, E. (2021). Desert locust upsurge and its socio-economic impacts in East Africa. *African Journal of Food, Agriculture, Nutrition and Development*, 21(2), 17654–17673. <https://doi.org/10.18697/ajfand.97.17654>

- Kassie, M. (2013). Resilience to climate change in agricultural communities: Challenges for smallholder farmers. *Climate and Development*, 5(2), 118–131. <https://doi.org/10.1080/17565529.2012.751893>
- Kimathi, E., Tonnang, H. E. Z., Subramanian, S., Cressman, K., Abdel-Rahman, E. M., Tesfayohannes, M., Niassy, S., Torto, B., Dubois, T., Tanga, C. M., Kassie, M., Ekesi, S., Mwangi, D., & Kelemu, S. (2020). Prediction of breeding regions for the desert locust *Schistocerca gregaria* in East Africa. *Scientific Reports*, 10(1). <https://doi.org/10.1038/s41598-020-68895-2>
- Kimathi, E., Tonnang, H. E., Subramanian, S., Cressman, K., & Guerschman, J. P. (2020). Predicting locust outbreaks under climate change scenarios in East Africa. *Scientific Reports*, 10(1), 1-11. <https://doi.org/10.1038/s41598-020-65925-x>
- Klein, I., Oppelt, N., & Kuenzer, C. (2021). Application of remote sensing data for locust research and management—a review. In *Insects* (Vol. 12, Issue 3, pp. 1–39). MDPI AG. <https://doi.org/10.3390/insects12030233>
- Kumar, K., Sinha, A., & Tiwari, S. (2020). Impact of insecticides on the environment: A review. *Environmental Science and Pollution Research*, 27(20), 24995-25005. <https://doi.org/10.1007/s11356-020-08849-3>
- Kumar, L., & Mutanga, O. (2019). Google Earth Engine applications in the assessment of vegetation health. *Ecological Indicators*, 98, 217-230.
- Le Gall, M., Magor, J. I., & Hunter, D. M. (2019a). Global distribution and diversity of locusts and grasshoppers. *Annual Review of Entomology*, 64, 267–286. <https://doi.org/10.1146/annurev-ento-011118-111847>

- Le Gall, M., Magor, J. I., & Hunter, D. M. (2019b). Cyclone-induced Desert Locust outbreaks in the Arabian Peninsula. *Pest Management Science*, 75(1), 15–23. <https://doi.org/10.1002/ps.5189>
- Lecoq, M. (2003). Desert locust management: Constraints and challenges. *Journal of Applied Entomology*, 127(9–10), 671–676. <https://doi.org/10.1111/j.1439-0418.2003.00818.x>
- Lecoq, M. (n.d.). Desert Locust Control"* at the Eighth Arab Congress of Plant Protection held in El-Beida.
- Loupa p, & Officer, P. (2019). Mobile Pastoralists : The Challenge of Livestock Markets in. 1–10.
- Lu, L., Kuenzer, C., Wang, C., Guo, H., & Li, Q. (2015). Evaluation of three MODIS-derived vegetation index time series for dryland vegetation dynamics monitoring. *Remote Sensing*, 7(6), 7597–7614. <https://doi.org/10.3390/rs70607597>
- Maeno, K., Piou, C., & Van Huis, A. (2019). Soil and vegetation characteristics related to egg-laying sites of the desert locust. *Insect Science*, 26(3), 442–452. <https://doi.org/10.1111/1744-7917.12560>
- Markle, H. (2008). The lifecycle and adaptability of locusts: A study on swarming and gregarization. *Journal of Insect Physiology*, 54(6), 593–601. <https://doi.org/10.1016/j.jinsphys.2008.03.001>
- Meynard, J. M., Lecoq, M., & Piou, C. (2020). Historical records of desert locust outbreaks and their association with climate. *Journal of Arid Environments*, 178, 104146. <https://doi.org/10.1016/j.jaridenv.2020.104146>
- Mubiru, D. (2010). Rainfall patterns in Uganda. *African Journal of Environmental Science and Technology*, 4(9), 601-609.

- Mulinde, C. (2019). Climate resilience among smallholder farmers in East Africa: A case study. Development Research Centre Press.
- Muwanga, S., Onwonga, R. N., Keya, S. O., & Komutunga, E. (2020). Influence of Agro-pastoral Activities on Land Use and Land Cover Change in Karamoja, Uganda. *Journal of Agricultural Science*, 12(9), 266. <https://doi.org/10.5539/jas.v12n9p266>
- Nakalembe, C., Dempewolf, J., & Justice, C. (2017). Agricultural land use change in Karamoja Region, Uganda. *Land Use Policy*, 62, 2–12. <https://doi.org/10.1016/j.landusepol.2016.11.029>
- Nakileza, B., Mutua, M., & Kitutu, K. (1999). Soil characteristics of the Karamoja region. Makerere University Press.
- National Environment Management Authority (NEMA). (2008). State of the Environment Report for Uganda. 265 pg.
- National Environment Management Authority. (2006/7). Uganda's environmental outlook: Wildlife conservation and land use in Karamoja. NEMA.
- National Environment Management Authority. (2008). Land use dynamics and environmental sustainability in Uganda. NEMA.
- National Environment Management Authority. (2010). Environmental impact of climate variability on agriculture in Karamoja. NEMA.
- Olum, D. (2017). Population and ethnic diversity in Karamoja. *Journal of Ethnographic Studies*, 11(3), 256-270.

Ould el Mamy, M., Roudier, P., & Sinha, A. (2020). Sustainable management of locust outbreaks: A review of biological control options. *Journal of Insect Science*, 20(3), 10. <https://doi.org/10.1093/jisesa/ieaa059>

Peng, W., Ma, N. L., Zhang, D., Zhou, Q., Yue, X., Khoo, S. C., Yang, H., Guan, R., Chen, H., Zhang, X., Wang, Y., Wei, Z., Suo, C., Peng, Y., Yang, Y., Lam, S. S., & Sonne, C. (2020). A review of historical and recent locust outbreaks: Links to global warming, food security and mitigation strategies. *Environmental Research*, 191. <https://doi.org/10.1016/j.envres.2020.110046>

Peng, W., Ordóñez, A., & Zhou, X. (2020). Impact of desert locusts on vegetation and agricultural communities. *Journal of Environmental Management*, 276, 111228. <https://doi.org/10.1016/j.jenvman.2020.111228>

Piou, C., Maeno, K., & van Huis, A. (2019). Soil moisture as a driver of locust density dynamics in desert regions. *Insect Science*, 26(4), 442–452. <https://doi.org/10.1111/1744-7917.12560>

Prior, C., & Streett, D. A. (1997). Strategies for desert locust control: Case study of biopesticides. *Agricultural Science Journal*, 3(5), 315–323.

Prior, C., & Streett, D. A. (1997). Strategies for the use of entomopathogens in the control of the desert locust and other acridoid pests. *Memoirs of the Entomological Society of Canada*, 171, 5–25. <https://doi.org/10.4039/entm129171005-1>

ReliefWeb. (2021). Impact of desert locusts on food security and livelihoods in East Africa.

Rigolot, C., de Voil, P., Douxchamps, S., Prestwidge, D., Van Wijk, M., Thornton, P. K., Rodriguez, D., Henderson, B., Medina, D., & Herrero, M. (2017). Interactions between intervention packages, climatic risk, climate change and food security in mixed crop–

- livestock systems in Burkina Faso. *Agricultural Systems*, 151, 217–224.
<https://doi.org/10.1016/j.agsy.2015.12.017>
- Roffey, J., & Popov, G. B. (1968). Environmental factors influencing locust egg hatching in desert areas. *Bulletin of Entomological Research*, 59(2), 231–241.
<https://doi.org/10.1017/S0007485300003295>
- Rugadya, M. A. (2013). Land and resource management in Uganda: Mining and conservation issues in Karamoja*. Uganda Land Alliance.
- Saini, R., Kumar, A., & Sharma, S. (2021). Desert locust invasions and control measures in East Africa. *Journal of Plant Protection Research*, 61(2), 189–196.
<https://doi.org/10.24425/jppr.2021.137035>
- Sharma, H. C. (2015). Integrated pest management: Strategies for locust control. *Pest Management Science*, 71(10), 1389–1400. <https://doi.org/10.1002/ps.4063>
- Sharmila, S. (2020). Cyclones and desert locust outbreaks in the Arabian Peninsula. *Meteorology and Climate Science*, 28(1), 123–135. <https://doi.org/10.1002/mcs.2030>
- Showler, A. T., Ould Babah Ebbe, M. A., Lecoq, M., & Maeno, K. O. (2021). Early intervention against desert locusts: Current proactive approach and the prospect of sustainable outbreak prevention. *Agronomy*, 11(2). <https://doi.org/10.3390/agronomy11020312>
- Showler, A. T., Piou, C., & Lecoq, M. (2021). Approaches to Desert Locust management: Impact and challenges of chemical and biological strategies. *Pest Management Science*, 77(1), 227–238.
<https://doi.org/10.1002/ps.6064>
- Skaf, R., Popov, G. B., & Roffey, J. (1990). The desert locust: an international challenge.

Philosophical Transactions - Royal Society of London, B, 328(1251), 525–538.
<https://doi.org/10.1098/rstb.1990.0125>

Skaf, R., Popov, G. B., & Roffey, J. (1990). The desert locust: Regional outbreaks and preventive control. *Crop Protection Journal*, 5(4), 261–273. [https://doi.org/10.1016/0261-2194\(90\)90045-T](https://doi.org/10.1016/0261-2194(90)90045-T)

Stephen, D., Simpson, S. J., & Sword, G. A. (2006). The role of phase polyphenism in locust population dynamics. *Advances in Insect Physiology*, 33, 1-40. [https://doi.org/10.1016/S0065-2806\(06\)33001-7](https://doi.org/10.1016/S0065-2806(06)33001-7)

United Nations Children’s Fund. (2020). Locust invasion threatening food security across East Africa.

United Nations. (2020). UN calls for urgent action to curb desert locust outbreak.

UNWP. (2020). Food insecurity in the Karamoja region: A special report. United Nations World Program, New York.

Vallebona, C., Genesio, L., Crisci, A., Pasqui, M., Di Vecchia, A., & Maracchi, G. (2008). Large-scale climatic patterns forcing desert locust upsurges in West Africa. *Climate Research*, 37(1), 35–41. <https://doi.org/10.3354/cr00744>

Van Huis, A. (2007). Strategies for desert locust control in Africa: Lessons learned from past experiences. *Annual Review of Entomology*, 52(1), 555–575. <https://doi.org/10.1146/annurev.ento.52.110405.091230>

Van Huis, A. (2007). Strategies to control the desert locust *Schistocerca gregaria*. *Area-Wide Control of Insect Pests: From Research to Field Implementation*, 285–296. https://doi.org/10.1007/978-1-4020-6059-5_27

- Van Leeuwen, W. J. D., Orr, B. J., Marsh, S. E., & Herrmann, S. M. (2006). Multi-sensor NDVI data continuity: Uncertainties and implications for vegetation monitoring applications. *Remote Sensing of Environment*, 100(1), 67–81. <https://doi.org/10.1016/j.rse.2005.10.002>
- Vani, B., & Mandla, V. R. (2017). Analysis of NDVI in satellite-based vegetation studies. *Journal of Remote Sensing Applications*, 14(2), 144-158.
- Vani, V., & Mandla, V. R. (2017). Comparative study of NDVI and SAVI vegetation indices in Anantapur district semi-arid areas. *International Journal of Civil Engineering and Technology*.
- Veran, S., Lecoq, M., & Piou, C. (2015). Locust outbreaks in the Americas: The Rocky Mountain Locust. *Agricultural History*, 89(2), 223–237. <https://doi.org/10.3098/ah.2015.89.2.223>
- Veran, S., Simpson, S. J., Sword, G. A., Deveson, E., Piry, S., Hines, J. E., & Berthier, K. (2015). Modeling spatiotemporal dynamics of outbreaking species: Influence of environment and migration in a locust. *Ecology*, 96(3), 737–748. <https://doi.org/10.1890/14-0183.1>
- Wang, G., Maeno, K., Piou, C., & van Huis, A. (2021). Environmental determinants of Desert Locust outbreaks in East Africa. *Global Ecology and Conservation*, 25, e01312. <https://doi.org/10.1016/j.gecco.2020.e01312>
- Wang, L., Zhuo, W., Pei, Z., Tong, X., Han, W., & Fang, S. (2021). Using long-term earth observation data to reveal the factors contributing to the early 2020 desert locust upsurge and the resulting vegetation loss. *Remote Sensing*, 13(4), 1–19. <https://doi.org/10.3390/rs13040680>
- Westerhof, A. B. (2014). Precambrian metamorphic geology along the Uganda-Kenya border. *Geoscience Journal*, 9*(2), 45-57.

World Bank. (2020). East Africa's food security under threat from desert locust invasion.

World Food Programme. (2020). Karamoja food security assessment. World Food Programme

Yamano, T., Ariga, J., & Maruyama, E. (2021). Agricultural adaptation and resilience: Lessons from East African experiences*. Nairobi: African Economic Research Consortium.

Zhang, F., Zhang, L. W., Shi, J. J., & Huang, J. F. (2014). Soil moisture monitoring based on land surface temperature-vegetation index space derived from MODIS data. *Pedosphere*, 24(4), 450–460. [https://doi.org/10.1016/S1002-0160\(14\)60031-X](https://doi.org/10.1016/S1002-0160(14)60031-X)

Zhang, L., Lecoq, M., Latchininsky, A., & Hunter, D. (2019). Locust and grasshopper management. *Annual Review of Entomology*, 64(September), 15–34. <https://doi.org/10.1146/annurev-ento-011118-112500>

Zhang, L., Showler, A. T., & Lecoq, M. (2019). Environmental impact of pesticides in desert locust control: Assessment and challenges. *Environmental Toxicology*, 34(7), 815–823. <https://doi.org/10.1002/etc.4307>

Zhang, Y., Su, H., Zhang, L., & Zhang, B. (2019). The use of NDVI in vegetation monitoring. *International Journal of Environmental Research*, 13(5), 423-436.

Zhang, Z., Wan, F., & Yang, G. (2019). Desert locusts and food security in East Africa. *Global Ecology and Conservation*, 20, e00716. <https://doi.org/10.1016/j.gecco.2019.e00716>

APPENDICES

APPENDIX I: SURVEY QUESTIONNAIRE

Farmer Livelihood and Agricultural Production Baseline Survey – during locust invasion

Dear respondent,

My name is **Lutaaya Noah**, from Kyambogo University. We are conducting a study on **the effect of desert locust inversion on Vegetation, Crop production and Livelihoods in North Eastern Uganda**. Your participation is voluntary, but it is very important to participate because you represent many other people in this village. There are no wrong and right answers to the questions. Your answers will be used strictly for research purposes and will be treated as confidential.

Section 1. Household Information

01. Time of interview start:	_ _ _ : _ _	Time of interview end:	_ _ _ : _ _		
02. Team code.....				_ _	
Enumerator name			Enumerator code	_ _ _	
07. Signature of supervisor/team leader					

Section 2. Locust Invasion

<ul style="list-style-type: none"> a. Season of locust invasion b. Duration of invasion c. Drivers <ul style="list-style-type: none"> 1. Climate factors – rain, temperature, wind 2. Vegetation (fresh sprouting) 3. Bio-edaphic factors - Soil moisture, sand condition 		
08.	<p>In what cropping season did the desert locusts invade your area?</p>	<ul style="list-style-type: none"> 1. Before planting 2. After planting 3. During crop maturity 4. At harvesting 5. After harvesting
09.	<p>How long did the locusts invasions last in your area?</p>	<ul style="list-style-type: none"> 1. 1 – 2 weeks 2. 3 – 4 weeks 3. 2 months 4. 3 months 5. Over four months

<p>To what extent was locust invasion and breeding in your area favored by the following factors?</p> <p>(Rainfall, Temperature, Wind, Soil moisture, Sand & Vegetation)</p>		<p>Rate the factors on a scale of 1 – 4 where 1 indicates least favorable and 4 indicates most favorable).</p>
10	Rainfall	<ol style="list-style-type: none"> 1. Least favorable 2. Moderately favorable 3. Favorable 4. Most favorable
11	Temperature	<ol style="list-style-type: none"> 1. Least favorable 2. Moderately favorable 3. Favorable 4. Most favorable
12	Wind	<ol style="list-style-type: none"> 1. Least favorable 2. Moderately favorable 3. Favorable 4. Most favorable

13	Soil moisture	<ol style="list-style-type: none"> 1. Least favorable 2. Moderately favorable 3. Favorable 4. Most favorable
14	Sand	<ol style="list-style-type: none"> 1. Least favorable 2. Moderately favorable 3. Favorable 4. Most favorable
15	Vegetation cover	<ol style="list-style-type: none"> 1. Least favorable 2. Moderately favorable 3. Favorable 4. Most favorable

Section 3. Losses and damages

How did desert locusts' invasion affect vegetation, crop production and your livelihood?		
16	Vegetation	<ol style="list-style-type: none"> 1. Reduced plant cover 2. Increased bare ground 3. Reduced pastureland
17	Crops	<ol style="list-style-type: none"> 1. Interfered with crop sprouting, flowering and maturity 2. Increased costs of replanting 3. Interfered with the planting calendar due to need for replanting 4. Reduced shade and wind breakers in gardens 5. Reduced crop harvest
18	Livestock	<ol style="list-style-type: none"> 1. Reduced pasture land 2. Moving long distances to find pasture 3. Increased vulnerability to live stock pests and diseases 4. Reduced milk yield 5. Reduced meat yield
19	Livelihoods	<ol style="list-style-type: none"> 1. Reduced income from agriculture outputs 2. Reduced household food security 3. Increased incidences of food deficiency illnesses

13	Soil moisture	<ol style="list-style-type: none"> 1. Least favorable 2. Moderately favorable 3. Favorable 4. Most favorable
14	Sand	<ol style="list-style-type: none"> 1. Least favorable 2. Moderately favorable 3. Favorable 4. Most favorable
15	Vegetation cover	<ol style="list-style-type: none"> 1. Least favorable 2. Moderately favorable 3. Favorable 4. Most favorable

Section 4. Desert locusts' prevention and control measures and responsible organizations

20	Which preventive and control measures were instituted against desert locust's invasion?			
21	By which organizations/partners/agency?			
<p>Codes for 20: 1= aerial spraying, 2=ground spraying, 3=smoking/burning/lighting fires, 4=chasing/making noise 5= digging trenches to restrict locust movement, 6=biological control (using Fungus <i>Metarhiziumacridum</i> and the microsporidian <i>Paranosema locustae</i>), 7= Digging up egg pods or plowing fields infested with egg pods, 8= Scattering straw over roosting sites and then burning it),</p>				
	Measures	Who	Period	Thoughts on how to do it better

How effective were the above measures in combating desert locusts' invasion and breeding in your area?		Not effective	Somehow effective	Effective	Very effective
22	Aerial spraying with pesticides				
23	Ground spraying				
24	Smoking/Lighting fires to prevent swarms from settling in crops/ Use of flame throwers				
25	Digging trenches to restrict locust movement before invasion, driving hoppers into trenches and burning, drowning, or crushing them				
26	Chasing-making noise to prevent swarms from settling in crops				
27	Beating or trampling on the hoppers				
28	Biological control- using Fungus <i>Metarhiziumacridum</i> and the microsporidian <i>Paranosema locustae</i>				
29	Digging up egg pods or plowing fields infested with egg pods				

30	Scattering straw over roosting sites and then burning it				
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How effective were the above measures in combating desert locusts' invasion and breeding in your area?		3 = very good	2 = moderate,	1 = poor
33	Regarding the timing			
34	Regarding the place of application			
35	Regarding the method of application			
36	Regarding the care taken to protect animals and human beings			
37	Regarding the care taken against water pollution			
38	Training given to the community to protect themselves against the chemicals			
39	Regarding the effectiveness of the chemicals used			

APPENDIC II: FOCUSED GROUP DISCUSSION GUIDE

Day/Date: _____

Time: _____

Number of participants: _____

Participants

No.	Name	Sex	Telephone No.

Question 1.

In what cropping season did desert locusts invade your area?

Question 2.

How long did the locusts' invasion last in your area?

Question 3.

Which factors favored the invasion and breeding of locusts in your area?

Question 4.

How did desert locusts affect vegetation, crop production and livelihoods?

Question 5.

What preventive and control measures were instituted against desert locust invasion in your area?

Question 6.

Which organizations/partners were involved in desert locusts' control and/ or prevention?

Question 7.

How effective were the measures in combating desert locusts' invasion and breeding in your area?

APPENDIX III: FIELD PERMIT DATA ACCESS LETTER (S)



KYAMBOGO UNIVERSITY

P. O. BOX 1 KYAMBOGO
FACULTY OF ARTS AND SOCIAL SCIENCES
DEPARTMENT OF GEOGRAPHY AND SOCIAL STUDIES

11th May, 2021

TO WHOM IT MAY CONCERN
LUTAAYA NOAH
19/U/GMAG/18998/PD

This is to introduce to you the above named student who is pursuing a Master of Arts in Geography degree course at Kyambogo University. He is in his second and final year and he is supposed to conduct a research study entitled **“Effects of desert locust invasion on vegetation and crop production in North Eastern Uganda”**. His research is under the supervision of Dr. Barasa Bernard and Dr. Gabiri Geoffrey.

Any assistance accorded to him will be highly appreciated.

Thank you.

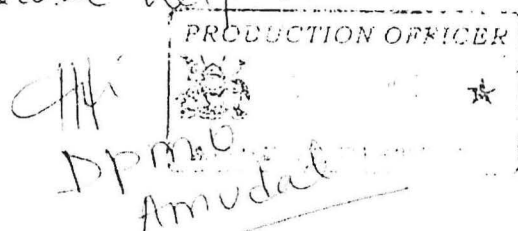


AGRIC. Officer T/C

DPMO
Handle

Please help him.

for
2/9/2021





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11th May, 2021

TO WHOM IT MAY CONCERN
LUTAAYA NOAH
19/U/GMAG/18998/PD

This is to introduce to you the above named student who is pursuing a Master of Arts in Geography degree course at Kyambogo University. He is in his second and final year and he is supposed to conduct a research study entitled **"Effects of desert locust invasion on vegetation and crop production in North Eastern Uganda"**. His research is under the supervision of Dr. Katusa Bernard and Dr. Gabiri Geoffrey.

Any assistance accorded to him will be highly appreciated.

Thank you.

(Signature)
Nabbosa Milly (Ms)
RESEARCH COORDINATOR



DP/10
Kindly assist the researcher to undertake their work

(Signature)
19/05/2021

(Signature)
02 SEP 2021

(Signature)
02-2-21





KYAMBOGO UNIVERSITY

P. O. BOX 1 KYAMBOGO
FACULTY OF ARTS AND SOCIAL SCIENCES
DEPARTMENT OF GEOGRAPHY AND SOCIAL STUDIES

11th May, 2021

*Admission
Granted
18/5/21
0774093010*

TO WHOM IT MAY CONCERN
LUTAAYA NOAH
19/U/GMAG/18998/PD

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Any assistance accorded to him will be highly appreciated.

Thank you.

M. Nabbosa Milly
Nabbosa Milly(Ms)
RESEARCH COORDINATOR

*Note of for Action,
B. S. Mwangi S.P.
3/09/2021*

APPENDIX IV: FGD ATTENDENCE LIST

Focus Group Discussion tool

Day/Date: 23.09.2021 (THURSDAY)

Time: 01:00 PM - 2:40 PM

Number of participants: TWENTY

Participants

No.	Name	Sex	Telephone No.	Sign
1	...	F
2	JOHN PAUL	M	07739171128	...
3	LIMANIK JESOP	M		
4	LIMAN PAUL	M		
5	Katharine Mayhew	F
6	NANGIAT BRIAN	M	0766601240	...
7	NANGI FRANCIS	M	0791523(1)8	...
8	Bocco Lubimungu	M	0759039961	...
9	AKESU JOHN SANDU	M	0789224833	...
10	KOLINYANG TOMILO	M		...
11	JUMA JAFUD	M
12	KALIMBA CHARLES	M	0750001141	...
13	FABIAN MARISSA JUMA	F	0782161326	...
14	BIMBISI ARVINI	F	0789777364	...
15	ORIELLO PATRICK	M	077522414	...
16	NANGI JOHN (S. N. J. J.)	M	0785525904	...
17	...	F
18	MORU JUMA	M	077900952	...
19	CHEBEL PENINIAN AMINI	F	0782161742	...
20	SIMBU BATHILO	M	0786826150	...